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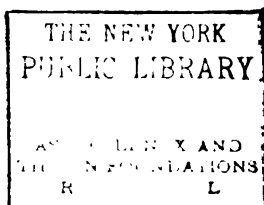
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PERS OF IRON

IN THE

VI ENGINE

W. H. H. H.

AND ABSTRACT

Vol. XVI

THE ASSOCIATION

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THE ASSOCIATION

MINUTES OF PROCEEDINGS
OF
THE INSTITUTION
OF
CIVIL ENGINEERS;
WITH OTHER
SELECTED AND ABSTRACTED PAPERS.

1
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for 1

EDITED BY
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CORRIGENDA.

- Vol. xc., p. 162, line 15 from bottom, *after* "on" *insert* "the."
 " " p. 176, line 21, *for* "Celynan" *read* "Celynen."
 " " p. 236, column 1, line 15, *for* "Walmesley" *read* "Walmisley."
 " " p. 436, line 15 from bottom, *for* "1805" *read* "1806."
 " " p. 547, line 20 and line 8 from bottom, *for* "calcium chloride" *read* "chloride of lime."
 " " " line 11 from bottom, *for* "oxides" *read* "oxide-salts."
 " " p. 548, lines 10 and 19, *for* "calcium chloride" *read* "chloride of lime."
 " xci., p. 265, line 9 from bottom, *for* "two" *read* "four."

THE
INSTITUTION
OF
CIVIL ENGINEERS.

SESSION 1887-88.—PART I.

SECT. I.—MINUTES OF PROCEEDINGS.

8 November, 1887.

GEORGE BARCLAY BRUCE, President,
in the Chair.

Mr. BRUCE, President, addressed the meeting in the following terms on assuming the Chair, for the first time, after his election :—

SINCE we last met here under the presidency of my esteemed predecessor, Mr. Woods, our Most Gracious Queen has completed the fiftieth year of her reign, and however hopefully the people of these realms, and of this vast empire, greeted Her Majesty when she first took her seat upon that throne, these feelings were but feeble compared with the deep sense of thankfulness and gratitude with which the nation can look back upon the reign of a monarch in whose life, through all these years, the dazzling light which strikes upon a throne has revealed no flaw.

As Her Majesty's loyal subjects we have had, and may yet have, many opportunities of reviewing these fifty years of her reign from various standpoints, social, commercial, political, and religious, all of which would be out of place within these walls. We, however, as an Institution and as a profession, have had our own part to play in the nation's and in the world's advance during these fifty years, and I do not know that I can do anything more fitting now than draw your attention to some of those changes which have come over the practice of the profession, and some of the achievements which it has accomplished during those years, so far as the limited time at our disposal this evening will admit.

In attempting this review I wish once for all to say, that I do not assume to teach anything, it is only in the position of a compiler of the record of the past that I open my lips.

To begin with this Institution. When Her Majesty came to the throne, on June 20th, 1837, there were 238 members of all classes. On June 20th, 1887, there were 5,396 members of all classes. And the total income of the Institution at the respec-

tive dates was £713 and £21,015, and beyond the increase of this Institution itself, we must notice that it stands as a mother amongst the nations. From it has sprung many kindred societies, dealing with sections of those great questions which fall within the all-embracing profession of a Civil Engineer, civil as distinguished from military. There is the Institution of Mechanical Engineers, of Telegraph Engineers, of Naval Architects, the Iron and Steel Institute, all of which we regard as helping to do, in sections, what it is committed to this Institution to have regard to and care for as a whole.

The profession must have believed thoroughly in the value of this Institution, and Society must have endorsed that estimate, or it could never have grown in numbers and importance as it has done. Times may change, numbers may diminish, but it is hardly conceivable that the value of The Institution of Civil Engineers to the profession and to the world can ever grow less.

As I entered the works of Robert Stephenson, in Newcastle, a few months before Her Majesty ascended the throne, in comparing things as they were then, and subsequently, with what they are now, I shall draw, to some extent, at all events, upon my own knowledge and experience, whilst in some departments I have had largely to depend upon friendly aid, generously given, and now most gratefully acknowledged.

ENGINEER'S WORKSHOP.

Having begun my profession in the workshop, it is not unnatural that I should look there first. There is probably nothing more striking than the change which has come over an engineer's workshop in these fifty years, and the most important feature of that change is the extent to which the use of machine tools has driven out hand-labour. In 1837 good workmen could chip and file by hand almost as true as a machine could do it; now I suspect there are but few who are adepts at the old art, the introduction of machinery having rendered it comparatively unnecessary. In 1837 there were in Robert Stephenson's shops no small planing- or shaping-machines, which now play so important a part in every engineer's shop. There was only one slotting-machine, the use of which was very restricted. Wheels were driven on to their axles by sledge-hammers, wielded by strong arms alone. Steam-hammers were of course unknown, and only hand-labour was available for the ordinary work of the smith's shop and boiler-yard, with the exception of the punching-

and shearing-machines. Riveting by machinery, and especially by hydraulic machinery, which has wrought such changes, and without which some work done now would hardly be practicable, was unknown.

It is scarcely credible, but it is a fact, that there was not a single crane in Robert Stephenson's shops in 1837. There were shear-legs in the yard, by which a boiler could be lifted on to a truck, and there were portable shear-legs in the shop, by the skilful manipulation of which, at no little risk of life and limb, wonders were done in the way of transmitting heavy loads from one part of the shop to another. And the only steam-engine in that which was the most important locomotive shop in the world of that day, was a vibrating pillar-engine, with a single 16-inch cylinder and 3 feet stroke. How changed is the shop of to-day, with its overhead traversers and its ground traversers and cranes, and appliances worked by power for lifting and moving heavy weights in all directions, with very little manual labour at all.

Time would fail me, and I may not attempt to speak in any detail of the power and efficiency of the tools of 1887, as compared with even similar tools which did exist in 1837. But, by way of illustration, I may observe that the heaviest planing-machine in Robert Stephenson's works in 1837, weighed probably not more than 3 tons, whereas to-day there is a planing-machine, standing near to the same place, which weighs 65 tons, showing an enormous advance in weight and power. And besides this increase in the size and capacity of tools, there are now machines for performing almost every operation that is required in an engineer's shop, with the least possible application of manual labour.

The introduction of steel in place of iron, and the immense size of marine-engines now constructed, have necessitated the adoption of machine-tools of a size and strength never previously thought of. We recently heard, in this Institution, of lathes 75 feet long, weighing 100 tons, and turning pieces weighing more than 60 tons, with four tools each taking a cut of $1\frac{1}{2}$ inch deep and $\frac{1}{4}$ inch thick, giving a yield of steel turnings at the rate of 10 tons per day of ten hours if worked continuously. Also of another lathe with eight tools which removes 20 tons of steel in a day of ten hours, on the same supposition of continuous working. Planing-machines are now made up to a weight of 90 tons, to deal with objects weighing from 60 to 70 tons, and operating over surfaces of 20 feet by 15 feet.

These are but illustrations of the enormous increase of power and capacity of tools now found in shops of engineers, and the

application of machinery in place of hand-labour is not less conspicuous in all other departments of an engineer's work. In a marked degree is this to be seen in the very extensive use of wood-cutting machinery, where fifty years ago there was nothing to be found but a circular-saw.

CHANGES IN THE POSITION OF WORKMEN.

It is interesting to observe the changes which have come over the condition and position of workmen themselves during the period under review. In 1837 the wages of an engine-erector in Newcastle were 23*s.* per week, working sixty-one hours; in 1887 the wages are 32*s.* per week, working fifty-four hours. The increase in money earned is 9*s.* per week, or 39 per cent. The rise in rate of pay per hour is from 4·52*d.* to 7·10*d.*, equal to 2·58*d.*, or an increase in wages per hour of 57 per cent.

The average wage per hour during the first twenty-five years was 5·03*d.*, and during the last twenty-five years it was 6·36*d.*, which gives an average increase of 26·4 per cent.

When we take into consideration that the prices of nearly all the necessaries and the ordinary comforts of life, with the exception of English beef and mutton, are greatly less than they were in 1837, it is very clear that the position of the British mechanic has immensely improved during the reign of Queen Victoria; for though I have only dealt with one class of workman, that is fairly representative of the rest.

We are constantly told that the difficulty Britain has in holding its own in the markets of the world is due to our want of technical education. There is something in this, but, in my judgment, comparatively little. The true cause of the difficulty is the large increase in wages and the diminution in hours of labour. It would be pleasant to think that this was not so, but I have not the shadow of a doubt, that it is the main cause of the difficulty of meeting foreign competition.

It is a matter of sincere congratulation that employers now really lay themselves out to care for the comforts of their workmen. There are rooms and halls provided where their meals can be cooked and partaken of comfortably, and where books and newspapers can be read, for all of which there was absolutely no provision in my young days. This is a vast improvement, for if any sin has in the past lain at the door of the British manufacturer, it has been in the direction of a want of care for the social, moral and religious surroundings and well-being of his work-people.

LOCOMOTIVES.

In locomotives great changes have been wrought since 1837; whilst, however, the main features of the engines of that time have been preserved, it is rather in their size, weight and power, and in the increased pressure of steam used and to be provided for, that the changes are to be found. In 1837, locomotives with which I, as a youth, had something to do were made at Robert Stephenson's, and sent on to the Grand Junction Railway to work the ordinary passenger traffic between Liverpool and Birmingham. These engines had 12½-inch cylinders, 5-foot driving-wheels, and weighed in working trim only 9 tons 12 cwt., of which 4 tons 7½ cwt. was on the driving-axle. The well-known "North Star," made for the Great Western Company in the same year, though it had 16-inch cylinders, with 16 inches stroke and 7 feet driving-wheels, only weighed, as registered in the books of the maker, in working trim 12 tons 12 cwt., a weight much less than is now put upon a metre-gauge railway. Locomotives used for similar duty on English railways in 1887 are of greatly increased power, weighing usually about 40 tons, with weights varying from 14 to 17 tons on the driving-axle, and are worked at a pressure of say 140 lbs. per square inch, being 2·3 times more than the pressure in use in 1837.

It should be noted that the bogie, which was in the first instance sent out to America from this country, has been now largely adopted in the land of its birth, where for so many years it was not recognised.

The only radical change introduced into locomotives has been the application of compound cylinders, upon which it is too early to pronounce any confident judgment based on experience.

PUBLIC WORKS.

In the construction of public works great changes have come over the practice of the profession during these fifty years, and these have been in a large measure brought about or facilitated by two main causes, viz., the very extensive introduction of iron and steel instead of masonry, and of concrete made with Portland cement for foundations, walls and other structures.

BRIDGE-FOUNDATIONS.

Fifty years ago or less, speaking generally, if the piers of a bridge or the walls of a dock required to be placed where sufficiently firm bearing stratum could only be reached at a con-

siderable depth below that at which it was convenient to place the masonry foundations, the plan followed was the insertion of timber cofferdams, and within these the driving of timber bearing-piles to the depth required to reach such strata. The number of bridges and other works in this country so constructed which have stood for centuries render it impossible to speak of such a mode of construction as in any way defective from an engineering point of view; though for other reasons it is not now very often followed. The facility and economy with which iron—and in some cases brick—cylinders filled with Portland-cement concrete can now be placed and sunk to any required depth, and brought up to any prescribed height has caused them to be adopted in the great majority of cases, and has wrought in a few years little short of a revolution in the sinking of deep foundations.

The bridging of some of the rivers of India which has been accomplished within this generation would hardly have been possible, or, at least, economically practicable, but for this mode of construction. As, for instance, where it has been necessary, from the treacherousness of the river-bed and the uncertainty of the stream, to sink the cylinders 100 feet and upwards to secure them against being undermined by a severe flood. Not that the plan of sinking cylinders or wells for foundations is absolutely new, for it is a very old one in India; but the native plan, in Madras at least, was to sink small brick wells, say 5 feet in diameter, to a depth of about only 15 feet, by divers who worked in no dress but that which Nature had provided. This limited the operations to very small depths. The whole bed of the river, for the width of the foundations of the bridge, was virtually covered with masonry, either piers or inverts resting upon these shallow wells. Such structures stood marvellously well, and were very cheap, but were, as will be seen, only applicable to river-beds which were dry in the working season, and where the torrent in the monsoon was not more than could be so controlled. A vast modification of principle and practice became necessary where great depths had to be reached in order to ensure the safety of the structure, and for this iron and Portland-cement concrete were necessary.

By the application of machinery such as it is not necessary here to describe, cylinders or caissons of the largest diameter, such as those used at the Forth Bridge, or of great depth though of more moderate diameter, as in many of the rivers of India, have been successfully dealt with, and works skilfully carried out which would have otherwise been impossible.

I may refer to a few of the bridges founded by means of cylinders or caissons.

The new Tay Viaduct, of which Mr. Barlow, Past-President, is the engineer, has main spans of 245 feet, each pier carrying which is formed of two iron cylinders 23 feet in diameter filled with brickwork and concrete, and sunk to depths varying from 20 to 30 feet into and resting upon sand, the depth of water at high tide being 23 feet. The weight borne by each superficial foot in the cylinders, including rolling load, is estimated at 3 tons.

The "Empress" Bridge over the Sutlej in India has spans of 250 feet, and each pier is formed of three brick wells of 19 feet outside diameter, and they are sunk on an average 110 feet into the bed of the river.

The bridge over the Ganges at Benares, with spans of 335 feet, has its piers composed of single iron caissons of oval shape 65 feet long by 28 broad, lined with brickwork and filled with concrete. These are sunk to a depth of about 100 feet.

The bridge over the river Hooghly, 30 miles above Calcutta, of which Sir Alex. Rendel and Sir Bradford Leslie were engineers, has a central cantilever carried on two piers, which were founded by means of wrought-iron caissons 66 feet long by 25 feet wide, with semicircular ends. These were sunk to a depth of 73 feet into the bed of the river, and 108 feet below the lowest water level. Each caisson had in it three compartments, through which the earth was excavated by means of vertical annular boring-shafts driven by steam-power, and armed at the bottom with radial cutters, which excavated circular holes of 10 to 15 feet. The material was removed by a current of water flowing up the hollow shaft and over a siphon into the river. The flow was maintained by pumping water into the excavating chambers and keeping it at a higher level than the water in the river.

In the foundations of the Forth Bridge the caissons are of very large dimensions, being 70 feet in diameter, and the deepest reached depths varying from 71 to 89 feet below high water, and from 39 to 43 feet into the bed of the Forth. In the case of the other bridges referred to (excepting that over the Hooghly), the caissons or cylinders were sunk by having the material excavated from the inside by means of grabs and other tools working from the open top, but in the case of the Forth, the pneumatic process was in the main adopted. The men worked in compressed air in a chamber 7 feet high, occupying the whole of the bottom surface of the

caisson, the chamber being filled with concrete after the caisson reached its proper depth.

One of the most remarkable instances of the sinking of foundations by means of iron caissons was exhibited in the erection of a graving dock at Toulon. Here the caisson was 472 feet long by 134 feet wide and 62 feet deep, and embraced the entire dock, which was built of masonry. The excavation necessary for sinking it was carried on, as in the case of the caissons for the Forth Bridge, by the use of a compressed-air chamber in the bottom of the caisson.

PORTLAND-CEMENT CONCRETE.

As already stated, the introduction of Portland-cement concrete has been a very important factor in the practice of the Civil Engineer in recent years. There is hardly any description of work which has not been rendered more easy, safer, and more secure through the use of Portland-cement concrete. We have had recently in this Institution Papers upon the use of concrete in piers in exposed sea-ways. We there saw with what facility the foundations of the structures were in some cases formed of large masses of concrete up to 100 tons in weight put into canvas bags and deposited in a plastic condition so as to accommodate the concrete itself to the inequalities of the foundation, when having done so it became as hard as stone. The application of concrete has also placed it within the power of the engineer to use, in the upper part of such piers, which bears the main force of the sea, solid and regular-shaped blocks of such dimensions as are far beyond what could have been procured and dealt with under the old system from a stone quarry however good. Each individual block has thus a power of resistance to the waves apart from any system of binding the blocks together (which might in either case be adopted) much greater than was heretofore possible. The largest blocks that have been dealt with, so far as I am aware, are those used at Dublin by Mr. Stoney, which were of the enormous weight of 350 tons each.

The use of this same material in place of brickwork or masonry in the construction of retaining-walls, whether for docks, sea-works, or other general purposes, so as to make such structures monolithic, though it may not improve the appearance of the work when completed, is no doubt an important engineering feature of the day in which we live, with which the engineers of fifty years ago were unacquainted.

MALEABLE-IRON AND STEEL IN BRIDGES.

Passing from this let us now look at an ordinary line of railway as made to-day and compare it with a similar line made fifty years ago. Apart from known developments due to increase of traffic, involving as this does, increase in weight of permanent way and rolling-stock, increase of accommodation at stations, vastly increased protection in the way of signals and telegraphs, the principal difference discerned will be the substitution of malleable-iron girder bridges for the brick or stone arched bridges of the earlier date. I am not here speaking of bridges of very large span, which are in most cases necessarily of iron, but of the ordinary road-, river- and accommodation-bridges where the engineer has the choice of adopting either stone or iron. Some difficulties and constructive dangers are avoided in putting up flat malleable-iron girders instead of arches. There are no centres to be made, and contractors prefer the iron, for they can easily calculate their profit. Whatever the cause, the graceful and time-honoured arch has largely given way to a substitute which has neither grace nor beauty about it, and which should therefore be avoided except where the physical conditions to be obtained, cannot be secured by the adoption of the arch. In this respect I venture to think that former days were better than to-day, that in the use of iron in this direction we have gone to an extreme, and that engineers would do well to retrace their steps, and not use flat iron girders where a brick or stone arch is admissible, to which such girders are greatly inferior both as regards appearance and durability. Where would the works of past centuries have been now had they been of iron?

Cast-iron arched bridges of considerable spans such as those over the Wear at Sunderland, with a span of 200 feet and 30 feet versed sine, and the Thames at Southwark with a span of 240 feet and 24 feet versed sine, and the Bonar Bridge in Ross-shire of 145 feet span and versed sine 21 feet, were erected in this country towards the end of last or the early part of this century; but malleable-iron bridges of large spans, which are now so numerous, and form so important a department of the work of the civil engineer in 1887, were (other than suspension bridges) all but unknown and untried in 1837. The stimulus given to this form of construction may fairly be said to be that which was applied by the Admiralty in 1845 in the conditions laid down by them, according to which the Menai Straits were to be crossed by the Chester and Holyhead Railway, and a free seaway for shipping preserved. In carrying out these conditions Robert Stephenson erected the rectangular tubular

girders of 458 foot-span without any scaffolding. And though this exact form of girder has not been frequently adopted, it cannot but be regarded as the prototype of all such large horizontal girders as have been erected since, whether made of solid plates or lattice framing, whether riveted or fixed with links and pins. And the erection of the Britannia Bridge gave an immense stimulus to the use of iron generally for bridges. The investigation necessary before the details of the design of the Menai Bridge were decided on, added largely to the knowledge of engineers in the construction of malleable-iron bridges, which knowledge subsequent investigation and experience have greatly increased.

It would be impossible within reasonable limits even to name the various large iron bridges which have since been erected all over the world. It will be sufficient as indicating the great size of iron or steel bridges now undertaken, to refer again to those to the foundations of which I have already drawn attention.

The Tay Bridge is 10,870 feet long, rather more than 2 miles. From the bed of the river to the underside of the girders is 100 feet; and the viaduct contains in all, approximately 18,000 tons of iron and steel.

The "Empress" Bridge over the Sutlej is 4,224 feet in length, with a total weight of iron in the structure of 6,704 tons, height from the bed of the river to the underside of the girders, 82 feet.

The bridge over the Ganges at Benares is 3,515 feet long. There is sometimes 100 feet depth of water in the river, and the height from the foundation of the piers to the underside of the girders is about 224 feet. The total weight of iron and steel in the structure is 7,600 tons.

The bridge over the Hooghly has two spans of 540 feet each; the height from the bed of the river to the underside of the girders is 118 feet, and greatest depth of water 86 feet, while the bridge contains 4,781 tons of steel and iron.

The bridge being erected over the Indus, which is of cantilever construction, and has a clear span of 790 feet, may also be mentioned.

In further illustration it will be interesting and instructive to place in contrast the largest viaduct now being constructed, with the epoch-making bridge over the Menai Straits.

The greatest span at the Menai is 459 feet; at the Forth it is 1,661 feet. The height of the top of the piers from the bed of the Straits at the Menai is 220 feet; at the Forth it is 570 feet. The height from the bed of the Straits to the underside of the girders at the Menai is 161 feet; at the Forth it is 360 feet in the centre.

The total quantity of iron at the Menai was 11,468 tons; at the Forth there will be nearly 50,000 tons of iron and steel. Truly a noble work to have been progressing during the celebration of the Queen's Jubilee, and one which no doubt when completed will be more astonishing in its day than even the Menai Bridge was in 1850, and will redound to the honour of our Past-President, Sir John Fowler, and our Member of Council, Mr. Baker.

RAILWAYS.

The progress of railways during the last fifty years may be shortly told. In 1837, as nearly as I can ascertain, there were under 200 miles of public railways open in the United Kingdom. In 1887 there are 19,332 miles open, representing a total capital of £828,344,254.

In British Colonies the length open is about 22,000 miles. In India in September 1886 there were 12,572 miles open, and the capital expended up to December 1885 was £166,146,651.

It is not possible to realise the full importance of this introduction and extension of railways as a factor in the world's progress and advancement, all within these fifty years.

MANUFACTURE OF IRON AND STEEL.

No greater change has come over any department within which the civil engineer is engaged than that which was introduced through the genius and skill of Sir Henry Bessemer, Member of Council, and followed up by one whose loss we so deeply deplore, our late Member of Council, Sir William Siemens, whose genius was only less attractive than his modesty. The inventions by which, within a generation, iron has been so largely driven out of the field by the introduction of a much better material, steel, produced at as cheap or cheaper rate, cannot but be regarded as one of the most wonderful achievements within the range of the Queen's reign. Before dealing with this, however, and as introductory to it, it is necessary to refer to the changes which have come over the manufacture of iron as distinguished from steel.

The extent of the iron trade in 1837 will be best gauged and expressed by the statement that in that year the production of pig-iron in the United Kingdom was somewhat under 1,250,000 tons, and that the average selling price of ordinary pig over the first five years of the Queen's reign was 77*s.* per ton; while we

shall not be far wrong if we put the production of the same in 1886, also in the United Kingdom, at 8,500,000 tons, with an average price of 35s. That is an increase in production of about seven-fold, and a diminution in price of 54 per cent.

How has this increase in production and diminution in cost been brought about?

The causes of the increased economy in production have been various. These were the more general introduction of the hot-blast; increased height and capacity of the furnaces; the utilization of the gases which previously had been wasted; the introduction of the regenerative stoves of firebrick, coupled with the more recent improvements which have been made in these.

The hot blast was introduced in Scotland by Neilson in 1828, but at the commencement of the period under review it was far from having been generally adopted; its use, however, gradually became universal, with the effect of increasing the productive power of the furnace 50 per cent. and upwards, and diminishing very largely the quantity of coal consumed per ton of iron made. On the first introduction of the hot blast it was used at about 600° Fahrenheit, and the heat was not materially increased beyond that until towards the year 1863, whilst perhaps the greatest heat obtained at any time by means of the now old-fashioned pipe-stoves was 1,000°.

Since the application of Sir Wm. Siemens's regenerative stoves of firebrick, in which our Member of Council, Mr. Cowper, has played a conspicuous part, and especially after the more recent improvements in these stoves, it is not uncommon to obtain a regular heat of blast of from 1,300° to 1,500° Fahrenheit, accompanied by material economy in the consumption of fuel.

As illustrative of the increase which has been made in the size of the furnaces, we may observe that a good furnace in 1837 was from 40 to 50 feet in height by about 14 to 16 feet wide at the bosh, and having a capacity of about 5,000 cubic feet. Such a furnace, worked with cold blast and open at the top, with its resulting gases going to waste, was only capable of producing say 70 to 100 tons of pig-iron per week, with a gross consumption of something like the equivalent of 6 tons of coal per ton of pig-iron made.

In 1887 the best type of furnace in the Cleveland district (which has become the largest and one of the most advanced iron-making districts in the world) is about 85 feet high by 22 feet wide at the bosh, having a capacity of 22,000 cubic feet, and a productive power of about 500 tons of Cleveland iron per week, with

the pressure and volume of blast at present in use. The gross consumption of fuel is equivalent to about 40 cwt. of coal per ton of pig-iron made, as against an average of about 6 tons of coal in 1837. The increase in the height of the furnace has resulted in the economy of fuel both by better preparation of the ore for reduction to the metallic state and by less waste of heat.

In America, by aid of larger and more extensive plant, they drive their furnaces harder and push the productive power much higher than we do. They have in some cases reached a productive power of about 2,000 tons per week per furnace, with a consumption of the equivalent of 34 cwt. of coal per ton of iron produced. The ore they work is, however, much richer, and also more easy of reduction, the plant per furnace more expensive, and the life of the furnace much shorter than in the Cleveland district of England. All things considered, there seems as yet no reason to believe that the American system would give improved results in Cleveland.

The utilization of the hitherto wasted gases was generally adopted about the year 1850. The gas under this system is now conducted to the engine boilers to be used in the raising of steam, and to the hot-air stoves to be applied to the heating of the blast; and Sir Lowthian Bell estimates that this use of the waste gases has effected a saving in the United Kingdom of 6,000,000 tons of coal per annum in the manufacture of pig-iron alone.

By means of all these improvements in the manufacture of pig-iron, the cost of making it per ton in this country may be estimated to be in 1887 about one-half of what it was in 1837.

Besides, and beyond the important change which has been effected in the extraction of iron from the ore of which we have just been speaking, there remains the still more important changes which have been introduced into the manufacture of steel from pig-iron.

There are three classes of iron in common use, viz., cast-iron, malleable-iron, and steel, and the ruling factor mainly giving to each its distinguishing characteristic is the proportion of carbon in combination with the iron in the three conditions.

Cast-iron usually contains about 4 per cent. of carbon; malleable-iron about 0.1 per cent.; while steel, in its great diversity of qualities in modern practice, varies from about 0.12 to 2.0 per cent. in its proportion of carbon. Mild steel, used for plates containing up to, say, 0.25 per cent.; rail-steel, generally somewhat over that proportion up to, say, 0.48 per cent. of carbon; steel,

with the highest percentage of carbon, being that which is used for tools.

These proportions of carbon it is which mainly, but not exclusively, give to cast-iron its special characteristics of fusibility at moderate temperatures, hardness and brittleness. To malleable-iron infusibility, except at great heat, thorough malleability and power of welding. To steel, greater tenacity and elasticity than either; and in the case of most qualities of steel the property of receiving temper.

Steel fifty years ago was very costly to manufacture, and was sold at about £60 a ton. No wonder it was little used except for arms, tools, cutlery, and springs. In the present day, by the aid of the Bessemer converter and the Siemens regenerative furnace, steel of great practical value, though not perhaps of all qualities, is produced at a cost in many cases less than malleable-iron; whilst, with the assistance of the Thomas-Gilchrist basic process, steel can under either system be made from materials previously used only in the manufacture of inferior qualities of malleable-iron. In consequence of this steel can be produced, not only cheaply, but in abundant quantities, and it has been gradually, and is now surely, taking the place of malleable-iron in almost all the operations of the engineer.

The way in which this change has been brought about can perhaps be best recorded by stating shortly what was the old process of making steel and what is the new one.

The oldest, and prior to Bessemer and Siemens, the most favoured method adopted in the manufacture of steel, was that known as the cementation process, in which only high-class and expensive wrought-iron was used. Iron in bars embedded in charcoal in close vessels submitted to a moderate heat for a period of seven or eight days, was turned into blister-steel by absorption of carbon from the charcoal. This process of cementation in a Sheffield furnace is generally estimated to cost in fuel for the grate in heating the charge, 15 cwt. of coal per ton of blister-steel produced, besides $1\frac{1}{2}$ cwt. of charcoal placed in the closed vessel to supply the carbon for the conversion of the malleable-iron into blister-steel. To produce shear-steel, bars of blister-steel are made into a pile, then subjected to great heat, and the whole welded into one bar under the hammer. Double-shear steel is produced by the repetition of the same process with bars of shear-steel. Crucible- or cast-steel under the old system was and is produced by an elaborate and expensive process in which blister-steel is melted in crucibles and cast into ingots. Until recent

years, this process required 4 tons of hard coke to make 1 ton of cast-steel from the blister-steel. With the aid, however, of the Siemens regenerative gas-furnace, the consumption of fuel in the same operation has been reduced to $1\frac{1}{2}$ ton of coal as against say, 6 tons, which may be taken roughly as the equivalent of the 4 tons of hard coke previously required. This old and costly cementation process is still followed in making the finer classes of steel required for the well-known productions of Sheffield.

Such was the old process of making steel until the appearance of Bessemer's inventions. The end aimed at in making steel by the cementation process is to restore to the malleable-iron, which has been deprived of its carbon in the process by which it was changed from cast- to malleable-iron, a portion of that carbon. In the Bessemer process, the same principle applies, but it is cast-iron and not malleable-iron from which the steel is made.

By merely blowing air at high-pressure for, say, fifteen or twenty minutes, through molten cast-iron drawn from the blast-furnace into the Bessemer converter, this metal passes into the stage of almost pure iron, the operation expelling nearly all the carbon by burning it out, and rid the metal of most of the silicon by oxidizing it, and so forming it into slag. At the same time, by the rapid combustion of carbon and silicon, an amount of heat is produced sufficient without any additional fuel to hold in a fluid state the almost pure metal thus formed.

Having thus reached the first stage in the conversion of cast-iron into steel by the Bessemer process, the process is completed by returning to the nearly pure iron a small but in each case definite proportion of carbon. This is done by adding to the charge in the converter specific quantities of spiegel in some cases, or ferro-manganese in others, both being triple compounds of carbon, manganese, and iron. Whether the metal added at this stage is spiegel or ferro-manganese, the proportion of carbon and manganese in the added metal is accurately known, and the quantity added to the charge is regulated according to the quality of steel to be produced.

Manganese is desirable in the added metal, and in most cases absolutely essential, because it is a valuable agent in carrying off phosphorus, and in freeing the charge of any oxide of iron which may have formed in it, and of neutralizing in some degree the deleterious effect of such impurities as still remain in the metal.

Thus 7 or 8 tons of cast-iron brought hot from the blast-furnace is, in the space of half-an-hour, turned into steel ingots without the expenditure of any additional fuel, and ready to be rolled

into bars, rails or plates as may be required with a small additional expenditure of fuel in reheating. So rapid and inexpensive is the process by which the manufacture of steel has been revolutionized ! The proposal to add manganese to the metal in the converter was made by Mr. R. F. Mushet, at a time when, but for this, the Bessemer process bid fair to be disappointing in its results.

The above process, however, could only deal with the higher qualities of hematite pig-iron, having a maximum of 0.1 per cent. of phosphorus. In order to make steel from inferior pig containing over this amount of phosphorus, some further process is necessary. The removal of the excess of phosphorus from these poorer qualities of pig is effected by the basic process. It consists in the use of basic materials in contact with the molten metal, to induce a combination between such base and the phosphorus, so that the latter may pass away in the slag, the base used for this purpose being lime.

The basic process was originally designed to utilize for steel-making the more phosphoric pig-iron largely produced in various localities notwithstanding every effort on the part of the manufacturers to eliminate phosphorus from the pig. Besides accomplishing this, it has enabled the steel-maker to deal with much more highly phosphoric pig than was at first contemplated, and to use in the manufacture of such pig refuse-slag at present in the neighbourhood of old puddling furnaces highly charged with phosphorus. The value of phosphoric slag as manure, it is expected, will more than compensate for the cost of dealing with the phosphorus.

In the year 1861, Sir William Siemens brought out his regenerative furnace which, amongst its many other uses, is applicable, and has since been extensively applied, to the production of steel direct from the pig. The success of the Siemens or open-hearth system is due to the special power of this furnace to supply great heat to the charge on its hearth with great economy of fuel. In consequence of some subsequent modifications in the manipulation of the charge it is now usually called the Siemens-Martin process. The furnace is heated by gas, and has a double set of regenerative chambers which alternately absorb heat from the spent gas, and give it up to the fresh gas and atmospheric air respectively on their passing to the furnace for ignition. The products of combustion escape into the chimney at a comparatively low temperature. The charge in this reverberatory gas-furnace, as in the Bessemer converter, is pig-iron, which being melted ; into the bath of molten metal thus formed, certain propor-

tions of ore, of a pure character and of scrap steel, are added. In the reduction of the ore, the carbon in the pig is consumed, and when examination shows that both metal and slag are satisfactory, spiegel or ferro-manganese is put into the charge as it passes into the ladle, from which it is cast into ingots of steel to be dealt with as may be required.

The result of the Siemens-Martin process has been the production of a mild steel of so uniform a character that it can with safety be employed (amongst its many other uses) in the construction of steam-boilers, which application, as we shall have reason to observe when dealing with another subject, has been an important factor in the revolution which has been wrought in marine navigation.

It would be impossible on this occasion even to allude to the various important changes which have followed upon the introduction of the Bessemer and of the Siemens-Martin processes; but in nothing is the effect more marked than in the railway interest throughout the world, as will readily be seen when it is considered that steel rails, with a life far exceeding that of iron, are now produced at a price greatly below that at which iron rails were ever manufactured.

STEAM NAVIGATION.

Great indeed have been the changes effected during the last fifty years in the building of ships and in the means of their propulsion; these changes I will endeavour shortly to trace.

In 1837 the proportionate tonnage of steamers to the total registered tonnage of British ships was only as 1 to 41. In 1887 this proportion has become as 1 to 2·14. The average tonnage of all vessels in the British Register in 1837 was 108 tons, and of steamers alone at the same date the average tonnage was 113 tons. Now, in 1887, the average tonnage of these respectively for all vessels is 246 tons; and in the case of steamers alone, 476 tons. The average tonnage of steamers has therefore increased more than four times since the year 1837.

The total tonnage of all vessels on the British Register in 1837 was 2,792,646 tons, as compared with 9,246,051 tons in 1886; while the tonnage of steamers alone, in the same period, has increased from 67,969 tons to 4,318,153 tons.

In 1837 there were only about 230 vessels on the Register of British ships of over 500 tons; and no merchant vessels, save those of the East India Company, were over 1,000 tons; and there was

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then only one iron vessel on the Register at Lloyd's. Whereas in 1886 there were 4,883 sailing-vessels and steamers of 500 tons and above on the Register, and 2,829 of 1,000 tons and above, and 385 of 2,000 tons and above that size.

The first "Cunard" steamers, the "Britannia" and "Arcadia," were only 207 feet long, and breadth of beam 34 feet 4 inches; and the first steamer which regularly sailed between Liverpool and New York (beginning in 1838), the "Royal William," was only 175 feet long, and of 700 tons. Whereas we have now on the same route the "City of Rome," 550 feet long and 8,000 tons; the "Umbria" and "Etruria," 500 feet; and many others of like proportions.

I refer to these facts not merely as interesting statistics, but to bring out the fact that the use of timber in ship-building restricted the size of the vessels, which restriction has been removed by the substitution of iron or steel.

The use of timber in building ships reached its limit about the year 1850; but this limit did not exceed 300 feet in length. After that date iron, in the first place, and subsequently steel, began entirely to supersede the use of timber in the building of ships; and this change of material rendered increase of size and alteration of proportions practicable and safe. Timber sailing-vessels were seldom built of a greater length than three or four times their breadth; and though wooden steamers were sometimes made seven times their breadth, this involved very special iron bracing to secure safety. After the introduction of iron, the common rule for many years was to make the length ten times the breadth, which has since been modified in general practice to about seven and a-half to nine times in the swiftest steamers.

No serious attempt had been made up to 1837 to promote ocean steam navigation. Coasting-service there was; but the large consumption of coal in the early days of marine engines, of which there is no very reliable record, but which was probably as much as 9 lbs. of coal per indicated HP. per hour, rendered it impossible commercially to undertake voyages to great distances from the point of supply of coal.

The "Sirius" was the first vessel to steam across the Atlantic, which she did in 1838, performing the voyage in seventeen days, which now occupies seven; and this voyage did almost as much as that of Columbus himself to open up the new world.

In the year 1837 all steam-boats were propelled by paddle-wheels of the radial kind, ordinarily with fixed floats, though some were made to feather. Various designs of engines were employed for driving the paddles. The most common, was the "side lever,"

which may be regarded as the type of the marine engine of that period, at all events for ocean-going steamers. It will be in the memory of the older members that in the year 1840 the "Archimedes" steamer, fitted with a screw-propeller, made a voyage round the coasts of Great Britain, calling at various ports to exhibit the first practical introduction of the screw in place of paddles, which, for ocean-steaming, it has now almost entirely displaced. The introduction of the screw was gradual, and as late as 1862 the Cunard Company built the large steamer the "Scotia" with paddles. That, however, was the last they so constructed.

Up to that date the improvement made in the marine engine was mainly due to an increase of size and power; gradually improved workmanship and design in details, and some economy gained by improved boilers and increased steam-pressure. This may be illustrated by reference to some of the Cunard vessels as follow:—

The "Arcadia" was built in 1840, and fitted with a pair of side-lever engines, with cylinders $72\frac{1}{2}$ inches in diameter, and 6 feet 10 inches stroke. The boilers were of the old flue type, and a working pressure of 6 to 7 lbs. The indicated HP. at sea was about 700, and the consumption of coal about 5 lbs. per indicated HP. per hour.

Subsequent paddle-steamers of the Cunard Company had engines of the same kind, of gradually increasing size, but still with flue-boilers, until the "Persia" was built in 1855. This vessel had cylinders 100 inches in diameter and 10 feet stroke, but was fitted with tubular boilers worked at a steam-pressure of about 20 lbs. per square inch. These engines indicated about 3,500 HP., and consumed about 4 lbs. of coal per indicated HP. per hour.

The "Scotia," built in 1862, had cylinders 100 inches in diameter and 12 feet stroke, with tubular boilers working at a pressure of 25 lbs. per square inch. The indicated HP. was about 4,000, and the consumption of coal a little less than 4 lbs. per indicated HP. per hour.

It will be seen that as the boiler-pressure increased the consumption of fuel decreased, but other conditions altogether were necessary before further economy could be secured.

The introduction of the screw-propeller necessitated an entire change in the design of marine engines. As it was necessary to drive the screw at a greater number of revolutions than it was deemed wise to drive the engines, the screw shaft was, in the earlier vessels, driven by the intervention of spur-gearing at a greater speed than the engine itself. By degrees engineers took courage and applied direct-acting engines, which are now universal for mercantile purposes.

The next improvement in marine engines was the introduction, or rather the revival, of the surface-condenser, about the year 1862, followed by gradually increasing pressures, the use of larger cylinders worked more expansively, by which the consumption of coal was reduced to about 3 lbs. per indicated HP. per hour.

As early as the year 1856, Messrs. Randolph and Elder had adapted for marine purposes the Woolf double-cylinder engine, having two high- and two low-pressure cylinders working on to two cranks; but no very marked advance was made until about the year 1868, when what has since been known as the compound engine, having one high- and one low-pressure cylinder working on two cranks, appeared.

The Woolf engine had produced undoubted economy, yet it was not regarded with general favour for marine purposes, owing to the complication involved in having four cylinders. As soon, however, as it was found that even greater economy could be obtained by using an engine with two cylinders, in no way more complicated than the ordinary engine then in use, a complete revolution in the construction of the marine engine took place, and the compound two-cylinder engine speedily displaced the ordinary two-cylinder engine and became the universal type.

With its introduction and the adoption of a boiler-pressure of from 50 to 60 lbs., the consumption of coal fell to about 2½ lbs., being a saving of 25 per cent. upon anything which had previously been done. The pressure of 60 lbs. per square inch in the boiler was then considered high, being about double the pressure in use before the introduction of the improved engine. Much more attention required to be given to the design and workmanship of the boiler than had been previously given. But with all this there was a practical limit which could not safely be passed so long as iron was the material employed.

It was not until about the year 1876 that engineers generally had confidence enough in mild steel, produced by Sir William Siemens, to use it for marine boilers, and by its introduction alone was it possible to go on increasing the boiler-pressure. In a few years compound engines came to be worked at a pressure of from 90 to 100 lbs. with a consumption of somewhat less than 2 lbs. of coal per indicated HP. per hour, or as Mr. F. C. Marshall, M. Inst. C.E., gave it in his Paper in 1881, 1·828 lb. Thus in 1880 a horse-power cost in fuel only a little more than one-third of what it had cost in 1837, estimating that at 5 lbs. per indicated HP., and it was probably usually a good deal more.

Compound engines with steam-jacketed intermediate receivers,

introduced by our Member of Council, Mr. Cowper, have reduced the consumption to about 1·6 lb. of coal per indicated HP. per hour.

Engineers did not, however, rest content with the economy thus far effected, and the only known way of advancing in this direction was by increasing the pressure in the boiler (which the use of mild steel made quite practicable), and at the same time carrying the expansion principle still further by the adoption of three cylinders instead of two. This has been done, and constitutes the last great step in the improvement of ocean-going steamers.

There are many of these now working with triple cylinders, at 160 lbs. pressure, and an expenditure of not more than 1½ lb. of coal per indicated HP. per hour, and these triple-expansion engines are fast displacing the compounds, as the compounds did the ordinary engine eighteen years ago.

Mr. Alexander C. Kirk, M. Inst. C.E., now the senior partner in the firm of Messrs. R. Napier and Sons, was, I believe, the first to design and apply the triple-expansion engine, which he did as early as the year 1874. The plan failed at that time to secure the attention which it deserved, and which it did not receive until seven years later, when another vessel was, under more favourable conditions as regards boilers, fitted with triple-expansion engines also by Mr. Kirk, for Messrs. Geo. Thompson and Co.'s Australian line. It would be easy to point to steamers in which the engines have since been altered from compound to triple expansion, where a reduction in the consumption of coal to the extent of 25 per cent. has been the result. The increase in speed since 1840 is indicated by the fact that the fastest passage made across the Atlantic by the "Arcadia" and "Britannia," the first of the Cunard steamers, was at the rate of 9·33 knots per hour, while the fastest passage made by the "Umbria" this year was at the rate of 19·4 knots per hour.

Some engineers, notably the firm of Messrs. Denny and Co., of Dumbarton, are even adopting engines which expand the steam through four cylinders successively, worked with a boiler-pressure of 170 to 180 lbs.; but the experiment is too recent to warrant judgment being pronounced upon it.

We have thus seen the successive steps by which, in our Queen's reign, the mercantile marine of the world has been changed. First the screw-propeller, then the introduction of iron and steel in the building of ships, then the increase of pressure in the boiler and the introduction of surface-condensers, followed by the use of compound and triple-expansion cylinders, and a much larger increase in boiler-pressure, rendered possible by the use of

mild steel in the construction of the boilers, effecting in all a reduction of at least 70 per cent. in the consumption of coal per indicated HP., and an increase of 110 per cent. in speed. And without pretending to be a prophet, it is no presumption to predict that the ultimate limit of saving or speed has by no means yet been reached.

The whole subject of marine engines, especially in reference to the consumption of fuel, was very ably and exhaustively treated by Sir Frederick Bramwell, Past-President, in a Paper he read in 1872, before the Institution of Mechanical Engineers, and also by Mr. F. C. Marshall, M. Inst. C.E., in 1881, before the same society; and again by Mr. W. Parker, M. Inst. C.E., Chief Engineering Surveyor of Lloyd's, before the Institution of Naval Architects in 1886.

SANITARY ENGINEERING.

During the Queen's reign that branch of engineering which is associated with the sanitary improvement of our cities, towns, and villages, may be said, with almost literal accuracy, to have been called into existence.

In 1837 such drains as were in use in towns were applied almost entirely for the conveyance of rainfall to the rivers or natural watercourses, while the dejecta of the population and the domestic refuse of all kinds were discharged into cesspits, or other receptacles, in close proximity to the dwellings, and not unfrequently under the very roofs.

At the same time water was almost universally obtained from shallow wells, dug in the ground near to these cesspits, where of necessity the water was polluted in the worst possible manner by the infiltration of the liquid contents of the cesspits. When water-closets were first invented they discharged into these cesspits, but as this intensified the nuisance, overflows had to be provided into the rain-water drains, which thus became foul and offensive.

In this condition of things disease and death-rates were of necessity high; infant mortality was enormous, and only the strongest and fittest survived amid the insanitary surroundings in which the great mass of the population existed. Cases were by no means few where the annual death-rate in towns exceeded 30 per 1,000 of the inhabitants.

Public opinion was slowly educated on this question, and roused as to the danger involved, by the reports of such men as Mr. Edwin Chadwick and Dr. Farr. The system of registration initiated in the year 1837, embracing as it did not merely births,

marriages, and deaths, but a statement of the diseases which were the causes of death, provided, as Sir Douglas Galton truly stated, in his address at the opening of the last session of the Society of Arts, "the basis upon which all scientific sanitary investigation necessarily rests."

The cry for some change was imperative. The reports of the Poor Law Commission of 1839 to 1842 set forth certain remedial measures as necessary, such as the removal of all refuse from the streets and habitations, the introduction of the water-carriage system of sewerage, and the improvement of the public water-supply, the employment of trained civil engineers to devise and superintend the works, and the appointment of qualified medical officers.

In 1848 the first Public Health Act was passed by Parliament, and shortly afterwards, in many provincial towns, the work of the sanitary engineer commenced, embracing in many cases not only a new system of sewers, but a new system of water-supply.

The first town inspected and reported upon, under the Act of 1848, was Dover. This was done by our esteemed Member of Council, Sir Robert Rawlinson.

The problem at the time before the engineer was the removal by water-carriage from human habitations of all the dejecta of the population and the liquid refuse. For this purpose the old sewers of rough stone, neither true to line nor level, were utterly unsuited, and the normal condition of such, after a few years, was to be more or less filled with noxious deposit.

It is unnecessary to dwell on the discussion which took place in these early days as to the use of small circular stoneware pipes for removal of sewage, as contrasted with larger brick or stone sewers. The advocates of each system were probably led to take extreme views, which ultimate experience does not justify. There is no question, however, that the introduction of glazed stoneware pipes may be said to have inaugurated a new epoch in sanitary engineering, as by their cheapness and efficiency they have conduced very largely to the development of sanitary improvements, where without them this would hardly have been attainable.

Glazed stoneware pipes, and, where these are too small, egg-shaped brick sewers, both carefully laid, constitute the transmitting channel for the sewage now adopted by the engineer.

Until a comparatively recent date it was an instruction of the Local Government Board that all sewers should be made to act as land drains, and consequently more or less open joints in the

stoneware or brick sewers were not considered objectionable. Now, however, sewers of both kinds are made as watertight as possible, and percolation of the subsoil water is kept down to a minimum.

Possible difficulties and dangers from the use of stoneware pipes as sewers have been averted by the introduction of the plan of laying them in absolutely straight lines, both in plan and in longitudinal section, between any two points of inspection. This renders the detection and removal of any obstruction quite easy, which, prior to the introduction of this mode of laying, was a very difficult matter.

Even in the case of the egg-shaped brick sewers stoneware has been advantageously applied. Hollow invert blocks of this material give at once a flat square base for the sewer which is built upon it, and a smooth surface for the passage of the sewage ; it also provides during construction a drain in the bottom of the trench to clear away the subsoil water. Junction blocks of this material are also used for the connection of house and other pipe branches.

Having got the pipes and sewers perfect for the passage of sewage, there was soon manifest the nuisance of sewage gas passing through these communications into the dwellings of the people. Trapping of house drains was, in the first instance, very much trusted to in order to prevent this, but it was quite ineffectual, and there is no doubt that, in some cases, the new system of sewers was as fatal to life as the old system of cess-pits had been. In some respects the new system was worse, for formerly, when each house or group of houses had its own cess-pit, the arrangement involved separation and isolation, while under the new system all the houses were connected by their pipe branches with the same system of main sewers, and these became channels for the transmission of infective material from one house to another.

Diseases were thus transmitted, and a great outcry was raised against the use of water-closets, which happily was not successful, but which led to the adoption of means for remedying the evil. These consist in the extension of ventilation, interception and isolation. It is now known to be perfectly easy to prevent with absolute certainty the passage of sewer-gas into the interior of houses, and to mitigate almost entirely any offence from public sewers by providing numerous openings into them, so as to secure a full and free intermixture of common air.

The general adoption of the water-closet system, and the con-

centration of the fluid refuse of towns in one main sewer, soon gave rise to another serious evil, viz., the pollution of our rivers and waterways. When once the magnitude of this evil was realized, there were very many inventors who professed to be able to remove it, and, in the process produce a manure of such value as to prove a real commercial success. In this they have never yet succeeded, but great strides have been made towards getting rid of the sewage without defiling the rivers, and of turning the sewage at the same time to useful agricultural purposes.

There are still, however, many towns and districts which continue to pollute the streams and rivers by discharging crude sewage into them. Notably is this the case in the valley of the Thames just above the Metropolis. This blot, it is to be hoped, will soon be wiped out, for there is no reason why it should be allowed to continue.

London itself has possessed for twenty-five or thirty years a very fine system of intercepting sewers, but which is now becoming very severely taxed by the increased volumes of rain water and of sewage passing into it, due to the vast growth of the suburban population. To meet these conditions a very large outlay has been incurred to reduce the quantity of surface-water passing into, and gorging, the intercepting mains. Although the discharge of the sewage into the Thames takes place at $11\frac{1}{2}$ miles and $13\frac{1}{2}$ miles respectively below London Bridge, grave complaints have been made of the offensive condition of the river in dry and hot seasons. Sir Joseph Bazalgette, Past-President, by whom the splendid system of Metropolitan drainage has been carried out, is seeking to remove all cause of complaint by separating in specially prepared tanks, by a chemical process, the solid matter in suspension, leaving a practically inodorous liquid to flow into the river. This solid deposit is to be taken out to sea in steamers constructed for the purpose. This arrangement, however, is only regarded as tentative, to be superseded by the removal of the outfall nearer to the mouth of the river, should the population of London continue to increase in the future as it has in the past.

Side by side with a good system of sewage-removal there must be a good system of water-supply, and although some large cities and towns have had this from early times, a very great development of this branch of engineering has occurred during the reign of Her Majesty. This will be realized more readily when I say that our octogenarian Past-President, Mr. Hawksley, has himself constructed about one hundred and thirty waterworks, some of them involving embankments across valleys approaching 100 feet

in height, and with foundations carried equally far below the surface of the ground.

The designing of such works, resulting in the diversion of the head-waters of rivers largely used for manufacturing industries, involved the construction of compensating reservoirs for the use of such manufactories. The various delicate questions involved in making this provision has led to the development of the science of meteorology in a very marked manner. Rain-gauges by hundreds have been erected, and the amount of rainfall and observations on evaporation and percolation, and the flow of streams draining specific areas, have been regularly and systematically recorded, greatly to the advancement of science.

In addition to gravitation works, many towns have been supplied by pumping from the larger rivers, involving such subsidiary reservoirs and filter-beds as may in each case be necessary.

The underground sources have not been overlooked. The red sandstone, the oolites, mountain limestone and chalk, have been tapped in numberless places by wells and headings, and utilized very largely for water-supply.

Along with the development of waterworks, there has been the improvement of pumping-engines, resulting in great economy in working; and the analytical chemist, microscopist, and physiologist, have all been playing their parts, along with the engineer, in protecting and improving our water-supply to the great benefit of the whole community.

What, then, has been the result of the efforts of the engineer in connection with the sanitary work which we have been endeavouring shortly to describe?

The death-rate in England was in many cases 30 in 1,000 per annum, where now it is below 20 in 1,000. And, as pointed out by Sir Douglas Galton, in England "the average annual number of lives in the five years, 1880 to 1884, saved by sanitary improvement has been 102,240."

Although some of this saving of life is no doubt due to the increase of temperance amongst the people, and some to advance in medical skill, there still remains a record noble almost beyond compare to the credit of the engineer as the benefactor of his species.

HYDRAULIC MACHINERY.

Amongst the changes which have taken place during the last fifty years, we must not fail to mention the introduction and extensive application of hydraulic machinery. As early as 1802

hydraulic power was used by Bramah for the working of cranes, but for some reason this was not followed up; and no general application of the transmission of power by water under pressure was adopted until Lord Armstrong, Past-President (then Mr. Armstrong), in the year 1846, placed on the quay at Newcastle-on-Tyne a hydraulic crane for dealing with ordinary merchandise in the manner now so well understood and so universally applied, and with which the name of Armstrong is so inseparably and so honourably connected.

Possibly few present will have any distinct recollection of the lifting and hauling appliances in use in the year 1837. It will, however, be within the knowledge of all that at that time, except in certain isolated cases, human labour was most generally, almost exclusively used in the lifting and handling of goods. Now circumstances are entirely changed, the powers of nature have been called in for the lessening of human toil, and such work we all know is now generally done through the intervention of some mechanical agency, and in this hydraulic power has played an important part.

The first crane made by Lord Armstrong already referred to was worked merely by the ordinary pressure in the water-mains of Newcastle. Its success was complete as regards the machine itself, and the same plan was followed in some other places, but the pressure of the water being variable and uncertain, it was found necessary in general practice to depend upon a steam-engine to impart the adequate pressure to the water.

The advantages of the hydraulic system consist in the convenient means which water affords of transmitting power from one point to another, say from some central station where a steam-engine may be developing that power to considerable distances round, as and when it may need to be applied. And further in the application of the accumulator, by which the power of the steam-engine is stored and distributed, and which compensates for the intermittent working of the machines, thus rendering the work of the pumping engine approximately constant, and thereby effecting a great saving in the amount of engine power to be provided. There can be no doubt that the widely extended application of this power to all branches of manufacture and of commerce has been largely due to the invention by Lord Armstrong of the accumulator, which has made the application of hydraulic power independent of local circumstances and conditions. Were the power of the engine applied direct, without the intervention of the accumulator, it is probably within the mark to say, that on the average, at least three times the

pumping capacity would be necessary as compared with that now ordinarily adopted.

The firm of Sir William Armstrong & Co. has alone supplied engines for charging accumulators equal to a total of about 100,000 indicated HP., effecting a capital saving on the above basis equivalent to 200,000 indicated HP.

To attempt a brief description of hydraulic machinery and its gradual development is unnecessary, it is so well understood on all hands. It is, however, fitting to show some of the vast changes which have been wrought by the introduction and general adoption of hydraulic machinery, and the way in which a great commercial and manufacturing nation like Great Britain is dependent upon the successful application of this system.

Take the case of vessels. These, fifty years ago, entering or leaving a port, were, as a rule, entirely manipulated by hand, the same power being also used for working the dock-gates and other machinery, and for discharging and loading cargo. At present, on a vessel arriving at almost any dock in this country, the gates are opened, the vessel is hauled through the entrance, and has its cargo discharged or loaded, all by hydraulic machinery, and with amazing rapidity.

By way of illustration, but not as anything unusual, it may be mentioned that recently a steamer arriving at Liverpool from Calcutta, with a mixed cargo of rice, wheat, linseed, &c., in bags, in all 3,643 tons, was discharged in twenty-five hours, or at an average rate of 146 tons per hour. Another steamer, also in Liverpool, with a similar cargo, was discharged at an average rate of 195 tons per hour. The cargo in each case was weighed, landed, and stored in warehouses ready for delivery. The ships' own cranes, however, lifted the cargo from the hold to the level of the quay.

At Surrey Commercial Docks grain is raised by 30-cwt. hydraulic movable cranes, which make 125 lifts per hour when delivering from barges with a Priestman grab, the height of lift averaging 30 feet, and the range of slewing about a quarter of a revolution. This rate of speed, though very quick, is surpassed at Dundee, where hydraulic jiggers raise 5-cwt. bales of jute through a height of from 25 to 30 feet at the rate of 240 lifts per hour.

The handling of grain, through the intervention of elevators at some of the ports in Great Britain, has been most usefully developed in connection with the hydraulic system. Grain is raised and distributed throughout the warehouses by means of elevators and bands actuated by water-power, resulting in great economy

of time and money. At Liverpool, these bands, running at the rate of 8 feet per second, convey 50 tons of grain per hour at the expenditure of one actual horse-power.

Hydraulic machinery has had an important influence upon the coal trade, it being generally used for the shipment of coal in situations where a high level system is inapplicable. A speed and economy in the shipment of coal have thus been effected which otherwise would have been impossible. A wagon with 10 tons of coal can be run on to the cradle, lifted through 30 to 35 feet, tipped, lowered and run off in one minute ten seconds; but the quickest rate in ordinary working is twenty lifts per hour. It is not uncommon for a steam collier of from 1,200 to 1,800 tons to enter a dock at high water, discharge her ballast, receive her outward cargo of coal, and leave at high water next day, all being done within twenty-four hours.

In discharging coal with proper hydraulic appliances, vessels of from 800 to 1,200 tons capacity are usually cleared in a single tide, a gang of eight men with one 15-cwt. crane discharging and weighing from 300 to 400 tons per tide.

The actual cost of shipping coal by the hydraulic tips has been given by Mr. John McConnochie, M. Inst. C.E., at 2½d. per ton, including weighing, use of railways round docks, locomotives, labour, interest on cost of coal-tips, and all other charges. It is not easy, nor is it always safe, to give comparisons of the cost of different modes of doing work. However, the official returns of the port of Calcutta show that the cost of working hydraulic as compared with steam-cranes was as three and a half to one in favour of the former. This is a great difference, and may have been due to some conditions specially advantageous to the application of hydraulic power. At the same time, the uneconomical engine and boiler involved where there is one to each crane, and the length of time that such engines are left standing, will account for a considerable saving to the credit of the hydraulic system.

The importation of the large quantity of grain into Great Britain necessary for the food of the people, and the handling of the enormous import and export trade generally, has only been rendered possible, in great part at least, by the application of hydraulic power; indeed, I have the high authority of Mr. George Fosbery Lyster, M. Inst. C.E., for saying that but for this the business of the Liverpool Docks would be comparatively at a standstill.

The advantages thus briefly alluded to are by no means confined to docks and shipping; they meet us at every turn in life. The

land in our large towns is rendered more useful by the greater height to which houses and warehouses can be occupied with comfort and profit when provided with the lift and the hoist which the hydraulic system supplies. We, as yet, have only seen the beginning of a system, by which power is destined to be distributed in most of our cities and towns from central pumping-stations and large engines, with an economy of fuel and a facility of application probably unattainable by any other means.

We have already noted that the hydraulic system is largely applied to all kinds of riveting, whether of boilers, bridges or ships. It is to be seen doing most important work in dealing with the large steel slabs which have to be handled in our steel works, where thick plates of a size not hitherto thought possible are being rolled, and in the general business of a smith's shop in making forgings by squeezing the iron at a welding heat in dies, by which means work is done with surprising facility and economy.

It is becoming increasingly used in manipulating the traffic of railway stations, and is destined to still further extension, but it has not been possible to mention more than a few of the changes which the hydraulic system has already wrought and is yet destined to accomplish.

ELECTRICITY.

Amongst the changes which the civil engineer has had a share in effecting during the last fifty years, none has taken so strong a hold on the imagination of the world as the application of electricity to the work and wants of man.

Fifty years ago electricity was not applied to any practical purpose. It was known in the laboratory and to the man of pure science, but the mode of applying it to the production of light, heat, or motion in a practical way had not been discovered. Fifty years ago Cooke and Wheatstone introduced the electric telegraph. The principles concerned in this are of older knowledge than the past half century; it is mainly in the practical utilization of this older knowledge that advance has been made.

In working telegraphs we have chemical energy converted into electric energy through the galvanic battery, which, invented by Volta eighty-seven years ago, remains practically the same to-day, though it has undergone many improvements in form and efficiency. The discovery of Oersted that an electric current, passing over a magnetic needle, deflected that needle, was the fundamental principle on which Cooke and Wheatstone relied when they invented their means of indicating, by the electric

telegraph, words written by an operator miles distant. In principle it is the battery of Volta and the discovery of Oersted that rules to-day the working of our telegraphs.

What has the conjunction of these two ideas led us to? In the lecture Mr. Preece, Member of Council, gave some time ago in this Institution, he said that one million and a quarter batteries throughout Europe were employed for this purpose; that £30,000,000 of capital had been expended on submarine telegraphy alone, and that 80,000 miles of cable, which has since been increased to 110,000 miles, lie on the ocean-bed. In this country alone there are about 19,000 telegraphic instruments connected with the Post Office, and say 15,000 belonging to the railways, making in all 34,000, which roughly means one instrument to 1,000 head of population. This year it is estimated that 52,000,000 paid messages will have been transmitted, being one and a half for every man, woman, and child in the kingdom. This may convey some idea of the extent of the service rendered.

Then there is the huge advance of multiplex and automatic telegraphy, by which means we have reached the point of sending six messages at once on one wire, and, say, six hundred words per minute. The rapid rate could not be overtaken but for the system of automatic working introduced in very recent years by Wheatstone, and nurtured and improved by Mr. Preece. Cooke and Wheatstone began with a five-needle instrument, employing six wires, and working at the rate of about four words a minute; this passed into the less cumbrous and more speedy double-needle, requiring two wires, and now we have the single-needle Morse recorder, as well as acoustic instruments using only one wire, where the operator reads forty words per minute by sound, as well as, or independently of, the eye.

The practical use of the electric telegraph began in connection with the railway system, and no department of our national industry is to-day more dependent upon the telegraph for its efficient and safe working. Without the block system crowded traffic, such as that of the Metropolitan Railway, could not be worked with any approach to safety, and, but for the telegraph, the block system itself would be impracticable.

Following upon electric telegraphs, we have the much more recent invention of the telephone by Mr. Graham Bell. Electro-magnetic induction, discovered by Faraday, is the principle upon which this telephone, as well as the dynamo-electric machines, hereafter to be referred to, is based. In this telephone we have in the hands, both of the sender and the receiver of a message, a per-

manent magnet, surrounded at one pole by a coil of insulated wire, and close to that end of the magnet, and at right-angles to it, a thin iron disk. The human voice, impinging on this disk, causes it to vibrate, and thus to vary the magnetic field in which the coil of wire is placed, thereby producing, according to Faraday's discovery, undulating currents of electricity in the coil of insulated wire, which currents are transmitted by the line wire to the magnet at the other end of the circuit, and reproduce waves of motion in the disk there placed, causing it to emit sounds similar to, though feebler than, those originally uttered by the person speaking into the telephone.

The Edison transmitter is based upon another principle, viz., the varying conductivity of carbon under differences of pressure, however slight, while Hughes's microphone is based on the varying resistance of a loose contact. In each of these instruments batteries are used to generate the currents employed. It is a marvellous thing to be able to recognize the voice of a friend at 100 miles distance, but the doings of the telephone are too well known to allow of my dwelling here upon its wonders.

The progress of the application of the telephone has been much more rapid in America than in Great Britain, but here there are one hundred thousand "telephones in use as royalty-paid receivers and transmitters." There are 27,000 miles of telephone wires laid, and the number of messages sent in London alone has amounted to eighty thousand in one day.

Until very recently it was only chemical energy that was converted into electrical energy, but now we have advanced far in the direction of converting mechanical into electrical energy, by means of which we get light, heat, and power. This is done usually by a steam-engine, through the agency of the electro-dynamic machine, based on Faraday's discovery of electro-magnetic induction, where electric currents are produced by the motion of conductors in a magnetic field, or by the motion of a magnetic field in the neighbourhood of conductors. A magnet attracts certain metals. Work expended on breaking this attraction must be reproduced somewhere. Faraday discovered that if he wrapped insulated wire round the armature, the expended work was reproduced as electricity in that wire, and ever since engineers have been engaged in perfecting the practical application of this form of producing electricity.

As one important outcome of this we have electric light, which is finding its way, if by slow degrees, into every department of human life.

Light from electricity is, speaking generally, produced from the energy of electric currents through the medium of the Voltaic arc or the glow-lamp. In the former the circuit is broken by two rods of carbon, the points of which are at some distance apart. Then, as Dr. John Hopkinson, M. Inst. C.E., has expressed it, "the current has hard work to cross the air-space between the carbons, and the energy there developed is converted into heat, which raises the temperature of the ends of the carbon beyond any other terrestrial temperature." Hence the brilliant light.

In the glow-lamp great resistance is introduced into the circuit by the insertion of a slender carbon filament which is thus brought to a white heat by the passing current. Before the introduction of this lamp the use of electric light in private houses was hardly practicable; now it only needs further improvements in the way of economical production and storing to secure its universal application.

Perhaps it is in lighthouses that electric light has rendered the most striking service. Cost is there of little consequence as compared with the interests involved, so that this may be disregarded.

Sir James Douglass, Member of Council, gave, in a Paper read before this Institution, particulars of the introduction by him of electric light into the following lighthouses. At South Foreland, in each of the two lighthouses, there is a focal intensity of 3,040 and a condensed beam of about 152,000 candles, or 20 times more than the old light. In each of the two Lizard lighthouses there is a focal intensity of light equal to 11,800 candles, and a condensed beam of 330,000 candles, or 211 times more power than the old lights.

At the Souter Point lighthouse the focal intensity is 3,040 candles, and the intensity of the condensed beam is 700,000 candles.

In the Isle of May lighthouse, as described by Mr. D. A. Stevenson, there are two of De Meritens' alternate magneto-electric machines; the lamps are of the Serrin-Berjot type, and when both machines are running, the power in the arc is about 30,000 candles, the resulting beam of light is of 6,000,000 candle-power, or 600 times more powerful than the old oil light which was placed there just one year before Her Majesty ascended the throne. The light has been recognized by sailors 50 miles off by reflection from the clouds overhead, though the geographical range of the light is only 22 miles.

During the experiments carried on by the Trinity House at the South Foreland in 1884-85 for determining the relative merits of

electricity, gas, and mineral oil as lighthouse illuminants, arc lights of over 30,000 candles were successfully employed with lenses giving condensed beams of 18 million candles as actually measured by the photometer.

As illustrative of the intense heat that can be produced by electricity, it may be observed that it is now being used to reduce so refractory a substance as alumina. The electric dynamo which is doing this is of the Brush type, with an armature of 35 feet 4 inches in diameter. The current is conveyed to the carbon terminals at the hearth, and the space between these terminals is filled with carbon, and the material to be reduced. I believe I am correct in saying that there is no known substance which the current will not fuse. The cheap production of aluminium by this means to mix with other metals bids fair to be an important element in the manufacture of metals in the future.

The application of electricity as a motive power has been introduced, but has not as yet been largely developed. We find it in a few instances driving our tramcars. Where this is done the mechanical energy of a fixed steam-engine converted into electrical energy through the agency of a dynamo is conveyed to an electro-motor on the tramcar either direct or through the medium of secondary batteries, where it is reconverted into mechanical energy, which drives the wheels of the car. There are drawbacks in the way of the mechanical arrangements for the transmission of power by electricity for this purpose which have hitherto retarded its introduction, but there is every reason to believe that, in special cases at all events, it will be used for locomotion in the near future much more than it has been in the past.

Of what electricity is we know no more than our Father Adam knew. In that direction there has been no advance even in the reign of Queen Victoria. Still the progress in the application of the unknown, and perhaps unknowable thing, electricity, has been enormous during the last fifty years. That is to say, what electricity did for mankind in 1837 was virtually nothing; what it has done this half century later is huge. Electricity is to us now light, heat, and power. Our streets and beacons shine with it, it signs and speaks for us around the world, across the desert, and beneath the ocean; and when we shall have learnt the way of storing up in a more efficient and financially successful manner, the unemployed forces of nature such as the winds and streams and tides which can be so readily converted into electrical energy at trifling cost, then will it become a factor in the world's life compared with which the present is as nothing.

CONCLUSION.

It has not been possible to draw attention to other than the most prominent features of change which have come over things engineering during the reign of our gracious Queen. While to matters relating to instruments of war, whether guns or ships, I have purposely made no reference, the subject, though full of interest and importance, was too vast to be introduced. There is more satisfaction, too, in looking at the work of the civil engineer from its manifestly beneficent side. In viewing it as providing readier means for the passage of men and merchandise from one part of the earth to the other, whether by sea or land; for the advancement of commerce and all that concerns human weal and progress; helping to make famines impossible because the food of the lands blessed with "years of plenty" is brought ready to the aid of lands where for the time the "ears are withered and blasted."

There is something, too, more in accord with the sound of "Jubilee" connected with the reign of a Gracious Queen when we tell of progress which speaks of "peace on earth" rather than of progress in the provision of munitions of war, for war, inevitable though it may be, is always very terrible.

I cannot sit down, Gentlemen, without thanking you for the honour you have done me in placing me in this Presidential Chair, the highest seat a civil engineer can occupy. Noble men have sat here. To speak only of the dead, to me it is full of interest that I sit in the Chair once occupied by my revered master, Robert Stephenson; and it will be my aim whilst here to do nothing on which he would have looked askance; he whose career, entwined with that of his father, remains an instructive and pleasant memory to all of us who knew him, and within these walls will ever be a tradition never to be let go.

On the motion of Sir John Hawkshaw, F.R.S., Past-President, seconded by Sir John Fowler, K.C.M.G., Past-President, it was resolved by show of hands—

"That the best thanks of the members be tendered to Mr. Bruce for his address, and that he be requested to allow it to be printed in the Minutes of Proceedings."

The Telford and Watt Medals, the Telford Premiums, the Miller Scholarship and Miller Prizes, which had been awarded for the Session 1886-87 (see vol. xc. pp. 214, 215 and 216), were formally handed by the President to the several recipients.

15 November, 1887.

GEORGE BARCLAY BRUCE, President,
in the Chair.

(*Paper No. 2250.*)

"Accidents in Mines."

By Sir FREDERICK AUGUSTUS ABEL, C.B., D.C.L., F.R.S.,
V.P.C.S., V.P.I.C., Hon. M. Inst. C.E.

PART II.

IN summing up, in the first part of this Paper, submitted to the Members of the Institution last May,¹ the information extant relating to the possibility, under the existing improved conditions as regards the ventilation of coal-mines, of a contamination of the air by fire-damp to an extent to constitute *per se* an element of danger, the Author pointed out that, in well-ventilated mines, such contamination could only arise from a sudden and considerable liberation of gas in the form of a blower, or from a heavy fall of coal or stone, accompanied by a large escape of gas, occurring at, or in the vicinity of, the working-places; but that, in mines where firedamp occurs, and goaves and cavities of old workings exist to any considerable extent, where moreover the natural ventilation is only supplemented by comparatively feeble additional ventilating resources, a sudden fall in atmospheric pressure may be attended by the escape into the mine-ways of gas, to even a dangerous extent, from the accumulations which exist in those lurking-places, such escape being liable to occur even before a distinct fall of pressure has been indicated by the barometer.

Mr. Henry Harries has recently called attention to the fact that many colliery explosions have occurred during or immediately before anti-cyclonic disturbances, and, connecting this with the greater prevalence of mine-explosions during the winter months

¹ Minutes of Proceedings Inst. C.E. vol. xc. p. 160.

when the range of pressure is greatest, the barometer being usually high, he argues that the downward movement of the earth's surface, under increasing pressure, tends to force the gases pent up in coal and adjacent strata into the workings of deep mines, and that such movement may also give rise to the formation of minute fissures in the seams or strata through which the gases will pass into the workings with great rapidity. The Author has pointed out that the Royal Commission on Accidents in Mines was led, by a careful examination of systematic observations made or compiled by various trustworthy authorities, to conclude that, while certain coincidences of fall or rise of barometer with mine-explosions may be selected to support particular views or theories, no general connection has been established between colliery-explosions and barometric changes.

That gas-escapes from goaves, which are liable to accompany a sudden fall of barometer, constitute a not unimportant source of danger in coal-mines, was established by the concurrent testimony of many competent and experienced witnesses examined by the Commission. Mr. W. Morgans, of Bristol, who has given the subject much consideration, is strongly impressed with the view that colliery-explosions are in many instances either actually due to, or are greatly increased in extent and severity by, the condition of the deserted workings or goaves, in mines where firedamp is prevalent—a view which cannot but be shared by all those who have given attention to the condition of old workings in coal-mines. These goaves, which continue to extend in area as a coal-seam is worked away, are formed by filling up, or packing, the old working-places or gobs with the rubbish produced in working the seam. When this is thin, and the roof and floor are of a character to close in upon the packing by settlement and swelling up, the goaf may become so compactly filled up as to contain little or no spaces where gas can lodge. But where thicker seams are worked, the old workings are very rarely filled up more than partially, the available débris being insufficient for their complete packing. The more or less irregular subsidence, in large masses, of the roof overlying the cavities, is a natural consequence, and this is frequently attended by the formation of interstices in the upper part of the goaf, in consequence of the irregular form, and the hardness, of the dislodged blocks of stone; these spaces, as well as the caverns created by the fall of the roof over the goaves, form a system of cavities in which large volumes of gas may lodge, and which are often inaccessible to inspection or to anything approaching effective ven-

tilation. The low specific gravity of firedamp tends to maintain these upper spaces or cavities in the goaves charged with the gas occluded by the coal or adjacent strata. These facts were well established by the concordant evidence of many experts, collected by the Commission, as was also the very great difficulty, if not impossibility, on the one hand, of accomplishing more than an exceedingly imperfect or partial ventilation of goaves, and, on the other, of effectually drawing off the gas from goaves by special drain-arrangements, or of sealing the goaves so as to prevent the formation of explosive gas- and air-mixtures within them, especially when powerful ventilating currents sweep along different sides of extensive goaves at somewhat different pressures.

Mr. Morgans directed the attention of the late Commission to a possible connection of accumulations of explosive gas-mixture in goaves, adjacent to workings, with disastrous explosions, which certainly merits careful consideration. He pointed out that the settlement of those portions of worked-out strata overlying only partially packed goaves must give rise to the formation of considerable cracks and fissures, and that these may extend to, or close to, the coal or stone which is being worked at no great distance off; such fissures may become filled with explosive gas-mixture by the diffusion into them of some of the gaseous contents of the goaves from which they start, and may therefore convey flame from a fired shot to the magazine of more or less explosive gas-mixture, between which and the shot they serve as an explosive fuze or train. He refers to the fact that the examination of mine-workings upon which old goaves abut, after the occurrence of explosions, has led to the observation of instances where pack-walls, which have been so consolidated by pressure from above and below as to resemble the solid stone in hardness, have been found blown out into the road or working, which he regards as conclusive evidence of the development of great pressure by gas-explosions within the goaf, and as supporting his view that explosions may have originated in the goaves as indicated by him.

Mr. A. H. Stokes, one of Her Majesty's Inspectors of Mines, in some Notes upon the Report of the Royal Commission on Accidents in Mines,¹ comments upon that part of the Report which deals with the possibility of danger arising from gas-accumulations in

¹ Transactions of the Chesterfield and Midland Counties Institution of Engineers, vol. xv. p. 93.

goaves, and considers that, what at first may appear a dangerous state of things, arising out of the existence of extensive imperfectly packed goaves in a mine, is considerably modified by facts which he states as follows:¹ "It is very seldom, in long-wall working, that a goaf of 1 acre in extent, and having an average height of 3 feet, can be found standing open; and old workings should either be kept ventilated and examined, or stowed up when abandoned. In the second place, large and ably managed collieries are now so well ventilated, that any excess above an average of the gases given off, due to barometric fluctuations, is carried away unnoticed." It need scarcely be stated that these remarks do not affect the validity of the views advanced by Mr. Morgans. The fact that extensive goaves can seldom be found which are standing open, and the assertion that they should be either stowed up, or kept ventilated, affords no proof that they may not be magazines of gas or of explosive gas-mixtures, or that they are generally dealt with in one of the two ways indicated as proper methods of dealing with them, while, on the other hand, evidence to the contrary, and to the effect that the conditions essential to safety are difficult of fulfilment, was given by competent witnesses examined by the Commission. The statement that efficient ventilation removes "any excess above an average of the gases," which may be given off by goaves upon a sudden reduction of atmospheric pressure, is scarcely of a nature to controvert the fact that a large amount of gas may be discharged suddenly into mine-ways under the conditions pointed out by the Commission.

There is no doubt that, at any rate, many of the most extensive and disastrous explosions have occurred in mines (*e.g.*, at Abercarn, Dinas, Risca, and Swaithe Mine), containing extensive goaves which, where they have been only partially filled with débris, may have served as lurking places for large accumulations of gas, which the ventilating arrangements were powerless to deal with. While the roads and working-places of such mines may have been reported safe, as the result of the prescribed daily inspection, extensive accumulations of gas, or of explosive gas-mixture, may have existed in the vicinity of these places, ready for escape into the adjoining open spaces, upon a sudden change in atmospheric pressure. Such gas-escapes might either be fired through fissures or large cracks connecting them with the part of the seam or

¹ Transactions of the Chesterfield and Midland Counties Institution of Engineers, vol. xv. p. 117.

stratum where shots are being fired, or exploded when reached by the flame of a shot fired in the neighbourhood, this flame being probably increased in volume, or propagated so as to reach to a gas-laden goaf, by coal-dust employed in tamping the shot-hole, or by inflammable dust raised by the firing of the shot. To this extent Mr. Morgans admits that dry coal-dust in a mine is an element of danger, which, however, he regards as only of secondary importance as compared to the perils entailed by the existence of imperfectly-packed goaves in a mine.

That coal-dust does very greatly add to the dangers and increases the disasters caused by the existence of firedamp in mines, and that it may even, under certain special conditions, give rise to disastrous explosions, which but for its presence would be impossible, are facts now so conclusively established that the dangers have been officially recognized and to some extent, at any rate, dealt with, in the Coal-Mines Regulation Act of 1887, the passing of which must be admitted as ranking amongst the most useful of the work which Parliament has accomplished in the recent Session.

Eighty years ago Mr. J. Buddle, who was at the head of the Newcastle Coal Miners during nearly the first half of this century, directed attention, in a published account of an explosion in the Wallsend Colliery, to the destructive effects produced, at a distance from the point of first explosion, by the ignited dust; and fifty-nine years ago Mr. Robert Bald pointed out¹ that the blast of flame from a firedamp explosion might ignite the coal-dust deposits which covered the floor of many coal-pits in or near the working places. It was reserved for Faraday and Lyell to demonstrate, in their Report to the Home Secretary on the explosion in Haswell Colliery in September 1844, that coal-dust may be instrumental in greatly extending and in increasing the disastrous effects of firedamp explosions in mines.² The Author had occasion, in his opening Address to the Society of Arts³ in the Session 1885-86, and three years previously in a Discourse delivered at the Royal Institution,⁴ to refer to some salient points in the history of the development of knowledge regarding the part played by coal-dust in mine-explosions, and this interesting subject

¹ The Edinburgh New Philosophical Journal, 1828. Vol. 5, p. 101.

² Inst. C.E. Tracts 8vo. vol. 284.

³ Journal of the Society of Arts, vol. xxxiv. p. 21.

⁴ Royal Institution of Great Britain. Notices of the Proceedings, 28 April, 1882. Vol. x. p. 88.

is more exhaustively discussed in the final Report of the Accidents in Mines Commission; it will suffice for the purposes of this Paper to very briefly review the course of experimental inquiries, pursued upon a small and upon a large scale, by many investigators since the publication of the Report of Faraday and Lyell, which failed at the time, and for many years subsequently, to receive the attention it merited.

The extension of the destructive effects of coal-mine explosions by dust was dealt with, as an original observation, by the French Government Mining Engineer du Souich; ten years after the publication of that Report, and since 1875 the connection of coal-dust with mine-explosions has continued to be the subject of scientific and practical inquiry in France, England, Germany, and Belgium. In France, the observations of du Souich, Verpilloux, and Vital, have been followed by more extended investigations which Mallard and Le Chatelier carried out in connection with the French Mines Commission. In England, Galloway, Hall and Clark, Marreco and Morris, the North of England Institute of Mining and Mechanical Engineers, the Chesterfield and Midland Counties Institution of Engineers, the Author, and others, have pursued experimental investigations upon more or less parallel lines, and, in a few instances, upon a comparatively large scale, so as to approximate in conditions, at any rate in some respects, to those which obtain in a coal-mine. More recently a systematic series of experiments upon a very extensive scale has been carried out in Germany by the Prussian Firedamp Commission at the König Mine, in the District of the Saar, and the results there obtained have furnished conclusive evidence, on the one hand, of the possibility of coal-dust being the sole inflammable agent instrumental in the production of a coal-mine explosion, and, on the other hand, of the exceptional character of the conditions essential to bringing about such a result.

The fact that, in the complete absence of firedamp (or other inflammable gas) in the air, a sufficient coal-dust deposit in the immediate vicinity of a working, or the employment of coal-dust as the tamping of a shot-hole, gives rise to considerable elongation of the flame projected by a blown-out shot, has been abundantly demonstrated by the various experimenters; but it was very difficult to base reasonably acceptable deductions, as regards the way in which coal-dust may behave, under those conditions, in mine-workings and ways where the *perfect* freedom of the air from firedamp is demonstrable, upon the results obtained by experiments in models of mine-workings of only small dimensions,

and with arrangements very favourable to the thick suspension of dust in the air.

Only a few experiments upon a scale approaching the conditions which obtain in underground workings had been attempted when the Prussian Firedamp Commission was provided by that Government with the resources and arrangements necessary for practical experiments. That Commission speedily and amply confirmed the facts already established by experimenters in England and France respecting the power of coal-dust to increase and to propagate, generally to a comparatively limited extent, the flame from a blown-out shot, in the atmosphere of a mine quite free from inflammable gas; and they found, with most varieties of dust, that when the shot-hole was tamped with clay, 50 feet was about the maximum limit of distance through which the flame would be transmitted, while that limit was increased to about 70 feet if the shot-charge were tamped with coal-dust.

Among the numerous descriptions of coal-dust experimented with upon a large scale by the Commission, there was, however, only one variety, from "Pluto" mine, which combined the properties of very high inflammability, very fine state of division, and comparatively low specific gravity, to such an extent as to cause it to furnish explosive effects, approximating to those produced by a firedamp-and-air mixture, when a blown-out shot was fired in a gallery of similar dimensions to a mine-way, upon the floor of which the dust was thickly distributed, the air in the gallery being free from firedamp.

Similarly, in experiments previously carried out by the Author in a mine-gallery at Chatham, with a dust obtained from Leycett Colliery which resembled the so-called "Pluto" mine-dust above referred to, and which, in a series of experiments upon a smaller scale, with many varieties of dusts, had shown itself to be especially sensitive or inflammable, results were obtained approaching the exceptionally violent ones furnished by the latter. In the Prussian and Chatham experiments, the atmosphere in the galleries was known to be absolutely free from inflammable gas. In some much earlier experiments made by Messrs. Hall and Clark, in an adit which was driven from the surface into a seam of coal, and the atmosphere in which was stated to be "practically" free from firedamp, results of the same character as those above referred to were obtained, by spreading out a very fine coal-dust and firing a powerful blown-out shot at the far extremity of the adit.

Messrs. Atkinson, who, in their recently published work give

the results of very careful enquiries made by them into the data regarding the behaviour of coal-dust suspended in air,¹ and into several disastrous explosions in which they consider that coal-dust has played a prominent part, point out that the dust existing in one and the same mine-way varies greatly in regard to its ready inflammability and to the readiness with which it becomes diffused through the air, and that the dust deposited upon the sides, top-timbers and ledges in a dry, dusty mine-way, to which they give the name of "upper dust," is much finer and more inflammable than the "bottom dust" which covers the floors of such places more or less thickly, and which is frequently mixed to a considerable extent with dust produced by the grinding action of the horses' feet upon the bottom stone of the seam. Referring to the broad statement made by Mr. Galloway, that 1 lb. of coal-dust is the minimum required to form an inflammable mixture with 160 cubic feet of air, they point out that, upon this basis, in an area of 40 square feet, 1 lb. of dust is required for each length of way of 4 feet, and that, on dry and dusty haulage roads, a quantity of dust in excess of this proportion often exists as "upper dust" only, which has been raised at the working-places or from the floor-dust, during the passage of men and horses and of the trucks, much fine dust being shaken out from these, and deposited by the dust-laden air as it travels along.²

They also point out that while dust accumulations on the floor are necessarily removed from haulage roads in dusty pits from time to time, the deposits of "upper" dust are not interfered with. Messrs. Atkinson state that the coal-dust which collects in the higher parts of haulage roads becomes more inflammable than fresh coal-dust, and they incline to ascribe this to some chemical or physical change which it undergoes, possibly to the absorption of oxygen by the dust. In all probability, the increase of inflammability is due in part to the very complete desiccation which the upper deposits of dust, extended in thin layers over large surfaces in the warmest parts of a dry mine-way, must undergo, and partly to a still further disintegration of the powder, consequent upon the "weathering" of the particles. Moreover, the extremely finely-divided and very inflammable deposits of "dant," or so-called "mother-of-coal," which exist in more or less abundance in the

¹ "Explosions in Coal Mines." By W. N. and J. B. Atkinson. 1886.

² It may be here mentioned that, in the Prussian experiments just referred to, the proportion which the coal-dust strewn upon the floor bore to the area of the mine-way was greatly in excess of the above, being 1 lb. to 1 lineal foot of the gallery.

horizontal "partings" of coal-seams, is separated to a large extent from the coal-masses during the working and the underground haulage, and may sometimes constitute no inconsiderable proportion of "upper dust."

It would appear, therefore, that the exceptional character, as regards extremely fine division, extreme dryness and high inflammability, essential in coal-dust to enable it, when sufficiently distributed through the air, to transmit flame with great rapidity, may be presented by a class of dust which exists in dry and dusty mines, and is distributed over the workings of such mines to a greater extent than was formerly credited; that the propagation of flame by such dust, mixed in due proportion with air, may proceed with a rapidity approaching the transmission of explosion by a gaseous mixture; and that, even in the complete absence of fire-damp, an almost explosive combustion of dust may, under these conditions, possibly extend to distances which are only limited by a falling off in the abundance of the dust-supply, or by considerable changes in the area of the workings reached by the flame. In a very dusty mine, there is likely to be a considerable deficiency of oxygen-supply for the combustible material, and this, combined with the gradual progress of the flame along a dust-laden atmosphere (as contrasted with the rapid transmission of explosion by a gas-and-air mixture), must give rise, on the one hand, to only a partial burning, or even to only a charring of some of the dust particles, and, on the other, to the development of inflammable gas and vapours by the distilling action of heat upon some portion of the dust, the production of which may assist in promoting the propagation of flame.

Secondary, or back-explosions in mine-ways, of which the existence of distinct indications has been observed by Galloway in his careful examination of the effects produced by some disastrous explosions in mines where coal-dust had evidently played an important part, have been noticed in the course of the experiments of the Prussian Commission, and were also observed by the Author in some of his coal-dust experiments; they appear to be due either to gaseous combustible matter which has been developed from the highly heated coal-dust remaining unburned, or to gaseous products generated from them immediately after the first explosion; in either case, an explosive mixture would be formed at once upon the inrush of air, and would be fired by either incandescent or burning matter.

The possible action of coal-dust in connection with mine-explosions has been so far considered on the assumption that fire-

damp may be altogether absent, the dust itself being the sole inflammable agent instrumental in taking up, carrying on and developing to large proportions, the flame from a shot. The experimental results which serve to support the opinion entertained by some, whose views are entitled to great consideration, that certain coal-mine explosions have been practically caused by coal-dust, and are not ascribable directly or indirectly to fire-damp, are open to the criticism that those results are more or less exceptional in character, or that they have been attained under conditions which do not approximate to those likely to occur in a mine, more especially as regards the amount of dust suspended in the air, or the facilities created for its being raised in very large quantities at the time of, or by, the firing of a shot. It is urged that the various items of evidence, in support of what has acquired the name of "the coal-dust theory," collected in dusty mines after an explosion, such as, the deposition, and mode of deposition, of coked-dust upon timbers, ledges or floors in mines, and the appearance of burning or frizzling presented by dead bodies of men and horses after an explosion, though they furnished undisputable evidence that coal-dust had either played a more or less important part in the catastrophe, or had at any rate contributed to a considerable extent to the production of some of the effects, afford no proof that the presence of firedamp in the air of the mine, even if only in proportions so small that its existence has been unsuspected, or, the unexpected local invasion of workings or mine-ways by some small proportion of firedamp, may not have been the cause either of the origination of the explosion, or of its propagation, supposing its initiation to have been possibly due to coal-dust only.

It has been pointed out in Part I of this Paper that, up to the present time, the only method pursued of examining the air of a mine for firedamp is that of observing its effect upon the carefully-adjusted flame of a safety-lamp, and that the most skilful and experienced observers are scarcely enabled to detect, by this mode of testing, the presence of 2 per cent. by volume of pure firedamp in air. A working-place, or mine-way, may, therefore, be pronounced by a skilled inspector to be free from gas, and safe for the operation of blasting, when it actually contains at least 2 per cent. of firedamp. Now, although the existence of gas to that, or even to a decidedly larger, amount in the air of mines which is free from dust, or in a locality where no dust can be raised and suspended in the air by a disturbance of any kind, involves no danger, the presence of a very inflammable dust, even only in small quantities, in air containing such a propor-

tion of firedamp, or of a less inflammable dust thickly suspended in the slightly contaminated atmosphere, will render the mixture of air, gas and dust susceptible of explosion by the flame from a blown-out shot. The reciprocal influence of coal-dust and of firedamp in bringing about explosive effects under conditions, as regards the proportions in which they exist in air, when *either* would be harmless if the air contained *it* alone, is not only interesting but constitutes the chief element of danger of dust in a mine. Some varieties of inflammable dust which will not convey flame to any great distance if exposed to its action when thickly suspended in air free from firedamp, and travelling at a low velocity, will produce explosions under the same conditions, if the air contains only 1·5 per cent. of firedamp; on the other hand, a mixture of gas and air bordering in composition upon that which will just ignite upon the approach of flame, is instantaneously fired by a lamp-flame if it contains only very little dust in suspension. It was found by the Author that even a dust which is perfectly non-combustible, provided it be very fine and porous, will determine the instantaneous ignition of such gas-mixtures, an observation which explained why, in a series of experiments with a variety of coal-dusts differing from each other in physical characters as well as in the proportions of inflammable matter which they contained, certain dusts, comparatively poor in the latter ingredient, were found to rank among those most prone to develop explosions in air containing small proportions of firedamp.

It will be evident from the foregoing, that there is no need to assume that coal-dust, broadly speaking, is liable to give rise to explosions in mine-workings which are *absolutely free* from firedamp, in order to accentuate the danger of allowing any accumulation of dry dust to exist in workings where shots are fired, or of suffering considerable deposits of dust to accumulate in any mine-workings or mine-roads.

Neither are the serious dangers arising from the existence of dust-accumulations in collieries likely to become more impressed upon the mining public by the contention, which has been frequently maintained with much pertinacity in the public prints and in official publications within the last few years, that particular explosions have been examples of "pure dust explosions," when all that could be said in reference to the asserted freedom of the air in the mine at the time of the explosion from firedamp, has been that the mine was "practically free from gas" (as indicated, of course, by the only method of testing in use, the safety-lamp, which allows from 2 to 3 per cent. of gas to exist in the air

unnoticed); or, that there were "no accumulations of gas." The circumstance that safety-lamps were used in mines which furnished these supposed illustrations of pure dust explosions, showed that fire-damp was known to exist in the coal which was being worked, and the most careful and experienced inspector would not venture to assert that a small proportion of firedamp might not exist in the air, in the workings, which he had no means of detecting, or even that some accumulation of gas might not exist in inaccessible, though not hermetically sealed, cavities in the goaves. And, in all the quoted instances, the small proportion of gas, the very probable existence of which, at any rate, cannot be denied, may have been the determining cause of the propagation of the explosion by the dust through the mine workings. The formidable nature of dust as an agent of destruction is surely not in the least affected by the admission that the small proportion of gas generally essential to its operation as an explosive agent was, in all probability, there present. Let its absence in such collieries have been demonstrated at any time by Liveing's Indicator or by some other equally reliable means, instead of being assumed; there would then be reasonable grounds for the assumption that a "pure dust explosion" may possibly have occurred, but the danger of allowing accumulations of dusts to remain undisturbed in mines would not be emphasized thereby.

Messrs. Mallard and Le Chatelier, in the Report of their coal-dust-experiments,¹ combat the view that coal-dust has played a chief, or even a prominent, part in certain disastrous coal explosions which by some observers have been mainly, if not entirely, attributed to that agency. They point out that all such explosions of any magnitude have occurred in mines in which firedamp exists; they contend that the possibility of coal-dust, in the complete absence of firedamp, giving rise to an important explosion, can only be established by the occurrence of an explosion in a dusty mine in which the total absence of firedamp had been conclusively demonstrated, and they refer to the fact that no explosion has arisen in lignite-mines, which are free from firedamp but very dusty, the dust being of highly inflammable nature, as a demonstration of the impossibility of dust alone giving rise to extensive explosions. On the other hand, their own experiments have confirmed those of the English investigators, who demonstrated that the propagation of flame by coal-dust is promoted by the presence of firedamp in

¹ Recherches expérimentales et théoriques sur la combustion des Mélanges gazeux explosifs. 8vo. Paris, 1883.

the air in proportions insufficient to produce explosive mixtures *per se*, and that even non-combustible dusts will determine the ignition of a gaseous mixture, which in their absence is not inflamed. Results which Messrs. Mallard and Le Chatelier have themselves arrived at are, therefore, opposed to their argument that the influence of firedamp upon the inflammability of dusts, and *vice versa*, is much less important than it has been believed to be by others, and that coal-dust does consequently not play that prominent part in mine explosions the frequent exercise of which has been conclusively demonstrated. The validity of their contention, that no coal-mine accident of importance can be attributed with any claim to probability to the action of coal-dust, can scarcely be maintained against the results obtained with coal-dusts, in the absence of firedamp, by Galloway, Marreco and more recent experimenters, and especially by the large-scale experiments of the same class carried out by Hall and Clark, by the Author, and by the Prussian Commission. That the effects of transmission of flame by coal-dust in the absence of firedamp, though they may be very formidable if produced on an extensive scale (and the Saarbrücken experiments sufficiently indicated this probability), would be decidedly different from, and inferior in violence to, those produced by a firedamp explosion, or by an explosion of firedamp, coal-dust and air, was pointed out by the Author in his Lecture at the Royal Institution in 1882; the comparative suddenness of the gas-explosion would produce greater destruction and less burning effects than the comparatively gradual explosion, or rapid burning, of a mixture of coal-dust and air, or of such a mixture in the presence of a small proportion of firedamp. But, so far as regards destruction of life, there can be no question that an explosion in which coal-dust is prominently concerned, must, whilst being quite as disastrous as a firedamp explosion, assume a far more terrible character as regards the sufferings which it entails upon the victims.

The foregoing sketch of the nature of the dangers arising from the accumulation of dust in mines will, it is believed, sufficiently demonstrate the necessity for the measures relating to this subject insisted upon by the Royal Commissioners in the summary of their Report.

They point out that the constant removal of accumulating dust from the workings of dry mines, to such an extent as to guard against the raising of any dense cloud where shots are fired, could scarcely be so thoroughly accomplished as to constitute by itself an effectual precaution;—that the employment of hygroscopic or

deliquescent substances (such as sea-salt, chloride of calcium or chloride of magnesium), in conjunction with water, has not been shown, by practical experience, to afford trustworthy means of maintaining dust in a safely moist condition (especially in warm dry mines through which powerful ventilating currents pass), and, that the application of water, unless very efficiently carried out and within a brief period of the firing of powder-shots, would not be an effectual safeguard against the development of explosions through the agency of dust. While admitting that such an application of water may be not unfrequently attended with practical difficulties, they insist upon the exclusion of the use of powder from such localities unless the removal of dust from the workings, as far as practicable, is combined with copious watering of the floor, face, roof and sides, shortly before the shots are fired.

The practice of watering in dusty mines appears to have extended considerably, and it is maintained that the practical evils or inconveniences, which were expected to result therefrom, have not proved to be generally so serious as was anticipated by many. It need scarcely be urged, after what has been stated with regard to the comparatively very inflammable nature of the dust which, in dry mines, lodges upon the sides, roof, upper surfaces of timber, &c., that watering, to be efficient, must not be simply limited to the floors, but that it is most important to water the coal-face, and the upper parts of workings in the close vicinity of the shot which is to be fired. Very efficient and portable appliances exist by the employment of which a thorough wetting of upper dust can be accomplished with a comparatively small amount of water. In illustration, the Author may refer to a very efficient portable compressed-air hand-engine (Vinning's anchor-engine) of about the size of the ordinary extincateur, which is expeditiously and easily charged, and distributes the water with considerable force in the form of spray, which can be directed upon the dusty surfaces so as thoroughly to drench them, with the minimum amount needed for that purpose.

In carrying on shot-firing, the concussion and blast produced by the shot and the breaking up of coal by it give rise to a considerable amount of dust, independently of any that may pre-exist in close proximity to the shot-hole. In order therefore to guard against the addition to possible danger in consequence of the raising of dust, in places where a number of shots are to be fired at one time in proximity to each other, it is either necessary to fire such shots simultaneously, or to allow a sufficient interval between the firing of the individual shots to give time for the

dust raised by the effects of the explosion to subside or to be carried away by the ventilating current.

The only possible way, other than the removal of dust and application of water, by which the dangers arising from the getting of hard coal, or the removal of stone in the vicinity of coal in the presence of coal-dust and firedamp, can be avoided, would be, as pointed out by the Commission : the discovery of thoroughly reliable means for preventing the possible occurrence of "blown-out shot;" the adoption of particular explosive agents, or of particular methods of using such agents, which will deprive a blown-out shot of its danger by guarding against the possibility of a projection of flame, or of highly heated solid matter by the shot; or lastly, the substitution, for explosive agents, of some similarly efficient method of bringing down coal and stone, which is free from the special dangers attending the use of such agents.

Various methods and appliances have been proposed from time to time with the view of preventing the occurrence of blown-out shots; but neither the employment of highly resisting tamping materials, nor the attachment of heavy weights to tamping rods, and other contrivances of this class, have realized any approach to success in this direction. One of the latest devices for preventing blown-out shots, submitted to trial by the Commission, but without success, was a so-called blasting plug, devised by Mr. Humble, which consists of a perforated spindle corresponding in length to the tamping required, and having a screw-thread at each extremity; a conical brass nut with a broad base is screwed upon the lower end, a long cylinder of somewhat rigid vulcanized india-rubber is slipped over the spindle, and a broad-based nut is screwed down upon it, over the upper extremity of the spindle, so that the india-rubber cylinder or tube, which fits loosely into the shot-hole, into which this arrangement is inserted, may be expanded by screwing down this nut. The firing-fuze is passed through the hollow of the spindle. In long holes, the single india-rubber cylinder is replaced by several shorter ones, with intervening nuts in the shape of double cones, which, when the upper screw-nut is tightened, bring pressure to bear upon the individual cylinders. Several trials of these plugs showed them to be ineffectual in preventing the occurrence of blown-out shots, while their costly nature, even if they were fairly successful, would have constituted a grave obstacle to their extensive adoption.

Formidable danger frequently attends the employment of blasting-powder in coal-mines, on account of the flame which

generally attends, though to a very variable extent, the firing of a shot, tamped in the usual manner; and especially on account of the larger volume of flame which is projected to a considerable distance, either when a blast-hole is overcharged, or when the preponderating strength of the material operated upon, gives rise to what is termed a "blown-out shot," the tamping being projected from the hole like a shot from a gun. These sources of danger were recognized long before any views were advanced regarding the possible connection of coal-dust with mine-explosions, and the precautions enacted for ascertaining the absence of any important contamination of the air at the working-place with firedamp before shots were fired, and for reducing to a minimum the number of lives subject to possible danger when shot-firing was carried out, are well known.

Proposals have, from time to time, been considered by the Inspectors of Mines and others, for either abolishing the use of powder in fiery mines or for greatly restricting its application, by the imposition of more or less stringent conditions. When the Royal Commissioners gave this subject their attention and collected evidence bearing upon the dangers of shot-firing in mines and the possibility of dispensing with the practice, they were led to the conclusion: that the abolition, or even the very considerable restriction of shot-firing, as practised under the existing laws, would be incompatible with the working of a large number of pits, except at a prohibitive pecuniary outlay. Realizing most fully, on the other hand, the dangers frequently attending the use of powder in coal-mines and the extreme difficulty of effecting any important diminution of those dangers, they devoted much attention to the question whether it might be possible to discover any powder-substitute, or any method of using such substitute, which would secure immunity from danger due to the presence of coal-dust and firedamp in the localities where blasting had to be carried on.

From time to time assertions have been made as to the supposed comparative safety of different explosive agents, more or less analogous in composition to blasting-powder. The validity of such assertions is not difficult to put to the test by chemical examination of the particular explosive preparations, and it may be confidently maintained, from the experience which the Royal Commission and the Author individually acquired of preparations of this class, that there are but very few practically useful explosive agents of the gunpowder type which possess any advantage

in point of comparative safety over ordinary black or blasting-powder.¹

The employment of powder in the compressed form, which has of late years become very extensive, presents important advantages in point of convenience and general safety of handling, but does not in any way affect the dangers in reference to use in coal-mines, inherent in an explosive agent, the employment of which is liable at any time to be attended by the production of considerable volumes of flame. Attempts were made, in the earlier days of the history of gun-cotton, to apply that material as a blasting agent in coal-mines, but the circumstance that its explosion is attended by the development of a large proportion of carbonic oxide, renders it inapplicable in this direction, as its explosion (even by detonation) is liable, on that account, to be attended by the production of a considerable volume of flame. Finely divided gun-cotton may be readily incorporated with the proportion of a nitrate (saltpetre, or barium nitrate) necessary for the complete oxidation of its carbon, the generation of carbonic oxide being thus prevented or reduced to a minimum, and such preparations as nitrated gun-cotton, tonite or potentite, produced by compression of mixtures of this class, have found favour to some extent in drift work, or in the blasting of stone over- and under-lying coal-seams, as being more powerful than powder; but their explosion is by no means unattended with the possibility of the development of flame. In this respect, nitro-glycerine preparations are undoubtedly superior; this explosive agent contains a proportion of oxygen slightly in excess of that required for the complete oxidation of its constituent carbon, hence its perfect explosion is unattended by the development of inflammable gas. The most common form in which nitro-glycerine is commercially applied as a blasting-agent is the so-called dynamite, a mixture of the liquid explosive with from one-third to one-fourth its weight of a very porous siliceous earth, known as kieselguhr. When dynamite is exploded by detonation (the only efficient way of employing the so-called "high explosives") the heat developed by the metamorphosis of the nitro-glycerine raises to a bright red or white heat particles of the mineral matter (kieselguhr) with

¹ The name "Carbonite" has been given to one of the most recent of this class of preparations, stated by its makers, Buchel and Schmidt of Schlebusch, to be a safe explosive for use in fiery mines. Consisting as it does of saltpetre, barium nitrate, nitrobenzol and cellulose, its explosion would not be unattended with flame, and its use, therefore, is not likely to secure immunity from the dangers arising from blown-out shot.

which the liquid is mixed; hence the detonation of this form of preparation is always attended by the appearance of sparks in the dark. But if even the undiluted nitro-glycerine is exploded in a shot-hole, the high temperature has the effect of raising to incandescence particles of the tamping employed, or of the coal or stone exposed to the highly-heated gases and vapours developed, so that under any circumstances, sparks would be liable to be projected on the firing of a nitro-glycerine charge. The same holds good with any of the nitro-glycerine preparations known in commerce, such as lithofracteur, blasting-gelatine, or gelatine-dynamite; moreover, flame in more or less abundance may be produced by the explosion of some nitro-glycerine preparations, the composition of which includes proportions of inflammable materials.

That the heat to which very finely divided solid particles may be raised, by exposure to the highly heated products of detonation of nitro-glycerine preparations, is sufficient to determine the ignition of an explosive firedamp mixture, has been amply demonstrated by experiment, and it is even possible that sparks sufficiently hot to produce that result may be carried to some distance by the blast of heated gases projected by a shot, and thus reach places at some distance from the shot-hole where gas may have lodged.

The Author's long connection with the study of explosives, and their application to every variety of use, naturally led to his special devotion, as a Member of the late Commission, of much attention to this branch of its investigations; and the first idea bearing upon the occurrence of casualties in coal-mines which suggested itself to him, at the outset of the labours upon which the Commission embarked in 1880, was to apply the principle of most complete explosion, or detonation, of one or other of the so-called "high explosives" (chemical compounds highly susceptible of sudden metamorphosis into gaseous products or vapours), in conjunction with the method first devised by him in 1873, and communicated in that year to the Royal Society,¹ of distributing the operation of the force, developed by small charges of the explosive, over a considerable area, through the agency of a comparatively large volume of water, by which the charge is enveloped.

The principle of suddenly transmitting the force of detonation of a charge of explosive uniformly in all directions, by *completely surrounding with water* the charge to be detonated, had already been successfully applied by him to the conversion of an ordinary

¹ Proceedings of the Royal Society of London, vol. xxii, p. 160.

shell into a projectile operating with the destructive effects of a Shrapnel-shell, and to several other purposes, and it occurred to him that by applying the same principle to the charging of a shot-hole, the effect might be not only to modify the destructive action of a high explosive, and thus to attain a comparatively moderate splitting or rending action instead of powerful disintegrating effects, but also to accomplish the extinction, through the agency of the water envelope, of any incandescent particles or sparks, and perhaps flame, projected by the exploding charge, the water being thrown forward together with them, in a finely divided condition. It soon afterwards came to the Author's knowledge that Dr. McNab had previously put into practical execution the idea of extinguishing the flame of a *powder*-charge, projected from a shot-hole, by inserting a cylinder filled with water over the charge, and confining it by a small amount of tamping. The application of water in this way, in conjunction with powder, was also expected by Dr. McNab to effect an important economy of time in blasting operations, by diminishing the persistency of the smoke through the solvent action of the water, thereby enabling men to return to work in a comparatively short space of time after the firing of shot. The latter result appears to have frequently been attained to a useful extent, but experience showed, on the other hand, that sufficient reliance could not be placed upon the extinguishing effects of water, thus applied in conjunction with powder, being sufficiently exerted to afford reliable security against the ignition, by the flame from a blown-out powder-shot, of an explosive gas-mixture, or of dust thickly suspended in air containing a small proportion of firedamp. A series of experiments conducted for the late Commission indicated, however, that water-tamping, as first suggested by Dr. McNab, used in conjunction with a *high explosive*, such as dynamite, afforded very considerable, if not absolute, security against accidental explosions, under the conditions just now specified.

This method of using water appears to have been abandoned by Dr. McNab in favour of a mode of operating substantially the same as that proposed by the Author, experimented with by him and Mr. Smethurst at the Garswood Hall Collieries, near Wigan, in November 1880, and published in the spring of 1881.

An exhaustive series of experiments was instituted, chiefly in South Wales, for the late Commission, with a view to ascertain whether perfect security against ignition of explosive gas-mixtures, and of coal-dust thickly suspended in air containing a small proportion of coal-gas or firedamp, was secured by the application of high explosives in conjunction with water in the way suggested

by the Author, the charge of explosive being enclosed on all sides by water, with or without the additional use of superposed tamping. The methods of experimenting, which were of a searching character, and also included trials in mine-workings themselves, are described in detail in the final Report of the Commission; the results appeared to justify the conclusion that the so-called water-cartridge, employed in conjunction with a high explosive, could be relied upon to afford security against accidental explosions during shot-firing in the presence of explosive gas-mixtures, or of very inflammable coal-dust thickly suspended in air containing some small proportion of firedamp. The results obtained for the Royal Commission by the Author and by Mr. W. Galloway have been confirmed by experiments of a similar nature pursued by others in this country, by experimenters in Saxony, and by members of the Prussian Firedamp Commission. In the course of these various experiments it has been found that the particular form of dynamite to which the name *gelatine-dynamite* has been given,¹ on account of its physical characteristics, is especially suitable for employment in conjunction with water. Unlike ordinary kieselguhr-dynamite and similar preparations, its most important constituent, nitro-glycerine, is not displaced from it by even long immersion in water, so that it retains its explosive properties unimpaired under these conditions, and may, in blasting operations, be placed quite unprotected either in a shot-hole which is filled with water, or in a cylinder full of water, of suitable dimensions for insertion into the hole. In constructing a water-cartridge there is not the least necessity for employing any device for keeping the explosive in such a position that its circumference is surrounded equally on all sides by the water; it suffices simply to insert the charge, with its waterproofed fuze or wires, attached, into the blast-hole direct (if the latter is in perfectly solid stone or coal and in a suitable position), or into the cylinder of thin sheet metal, varnished paper or membrane, which is filled with the water; it is best, however, to insert the charge nearly to the bottom of the water, so as to utilize the tamping effect of the greater part of the column. The liquid is retained by a wooden or cork plug, through which the fuze or conducting wires pass, and tamping is applied over this after insertion of a tuft of hay or other suitable padding material.

The work done in coal by a high explosive, through the agency

¹ Gelatine-dynamite, like blasting-gelatine and some other modifications of the latter, is the invention of Mr. Alfred Nobel, to whom is due dynamite as well as the initiation of the technical use of high explosives, applied through the agency of detonation.

of a column of water which encloses it (or "water-cartridge"), is different in character to that accomplished by the same charge used in the ordinary manner. Instead of exerting a crushing action immediately round the charge, whereby much small coal is produced and no large amount of displacing work performed, the force being distributed over the whole area of the water-column; its action is thereby greatly moderated, and the coal is brought down in large masses, the work done extending over at least as large an area as that of the best powder-shots.

In applying this system as a safeguard against accidental ignition of coal-dust or firedamp-mixtures, the quantity of water used should at least amount to four times the volume of the charge employed. It has come to the knowledge of the Author that, in a colliery where a serious explosion recently occurred, so-called water-cartridges were in use, in which, when the charge of explosive had been inserted, very little room was left for water. From the published account of the evidence given at the inquest, it appeared to have been affirmed that Abel's water-cartridge had been used, at great expense, and it was left to be implied that the calamity was due to confidence being falsely placed in the safety to be ensured by its employment.

The mode of surrounding the blasting-charge of high explosive with water on all sides, which constitutes a "water-cartridge," was made public by the Author in the early days of the Royal Commission, and soon afterwards he repeatedly furnished to persons interested in mining simple instructions and patterns to serve as guides for the application of this system of blasting.

The practical development of the principle of applying water in conjunction with high explosives cannot fail to be fruitful of improvements in the mode of operation, as indeed it has already been; thus, in order to avoid a loss, or diminution, of the safeguard furnished by the water, from the escape of the liquid through channels or fissures in the shot-hole or through leaks in the water-cylinder or cartridge, it has been proposed by Messrs. Heath and Frost to dissolve sufficient size or glue in the water, warmed for that purpose, to make it solidify on cooling in the case or shot-hole to a sufficiently stiff jelly to prevent such escape. Again, the experiments carried out for the Commission with water-cartridges led to the observation, that a considerable proportion of the water was driven forward in a body instead of being dispersed in a very fine state of division, by the force of a blown-out shot, and a suggestion was consequently made for the employment of the water in a different manner, which was worked out by Mr. Galloway with most successful results, so far as related to the

extinction of flame and sparks from a blown-out shot. By distributing the water through a very porous body (such as sponge or moss), and thus effecting an initial interruption of continuity of the mass of liquid placed over the shot, its thorough dispersion in a very finely divided condition is ensured, and its extinguishing power is greatly increased. It was found, in a number of experiments at the Dowlais works, that in holes of 2 inches diameter the placing of 9 inches of loose tamping of moss, soaked with water, over a 4-oz. charge of dynamite sufficed to prevent the ignition of dust-laden air containing coal-gas by the blown-out shot, and that such a shot, produced with $2\frac{1}{2}$ oz. of dynamite, the charge being covered with only 4 inches of loose moss-and-water tamping, failed to fire an explosive gas-mixture. A number of comparative experiments demonstrated that the water-cartridge was on an equality with moss-and-water tamping in preventing the ignition, by blown-out shots produced with dynamite, gun-cotton, tonite and gelatine-dynamite, of a dense cloud of highly inflammable dust suspended in air containing a small proportion of coal-gas (the cloud, produced under the same conditions being invariably inflamed by an ordinary blown-out dynamite shot); but they proved that the water-cartridge did not afford that absolute security against the ignition of an explosive gas-mixture by a blown-out dynamite shot which, so far as a number of consecutive experiments showed, was attained by the comparatively simple moss-and-water tamping, which can be applied without difficulty even in holes having an upward inclination.

The water-cartridge, employed with various high explosives in such a way as to produce blown-out shots in the presence of coal-dust and gas, has been made the subject of official experiment in Prussia and Saxony, and apparently with results as satisfactory as have now been obtained in different mining districts in this country; it may be considered to have been conclusively established that the application of water in the shot-hole in one or other of the ways indicated, in conjunction with the use of high explosives, affords most important security against accidents in blasting stone or coal in mines where dust and firedamp co-exist.

It may be well again to emphasize the fact that neither the water-cartridge, nor water-tamping applied in the manner in which it has been found so thoroughly efficient in conjunction with high explosives, affords any safeguard against explosions arising from the presence of firedamp or of coal-dust associated with firedamp, in mine-workings where blasting is carried on, if powder, or any explosive agent analogous in its composition and

mode of explosion to powder, be employed in conjunction with them.

Suggestions have been made to use, in conjunction with powder, or as tamping over the charge, certain solid preparations which will evolve gases or vapours, when exposed for a sufficient period to heat, capable of extinguishing flame, the idea being that the heat developed by the explosion of the charge would accomplish the desired results, and that the dangers arising from blown-out shot might thus be guarded against;¹ but the authors of these suggestions have not realized the importance of time as a factor in the establishment of chemical changes by the action of heat, and the consequent impossibility of gases and vapours being evolved, in the desired manner, within the exceedingly brief period during which the materials applied are exposed to heat. The Commission, at the Author's suggestion, had experiments carried out for the purpose of ascertaining whether condensed (liquefied) carbonic acid could be applied, in suitable tamping vessels, in conjunction with high explosives, as an extinguishing agent, but the results were not sufficiently encouraging to warrant perseverance in this direction of experiment.

Some attention has been attracted, since the publication of the Commission's final Report, by a safety blasting cartridge brought forward by Dr. Kosmann of Breslau, which depends for its action upon the rapid development of hydrogen under high pressure from very finely divided zinc by the action of sulphuric acid (enclosed in one compartment of a compound vessel of glass). The acid is intended to have access to the zinc after the apparatus has been fixed into the shot-hole in such a way that the gas, which is said to speedily attain a high degree of compression, shall exert its force upon the stone or coal. The cost of each shot is stated to be only small, but the description scarcely warrants the view that the arrangement is a practically efficient one, and no account of successful experiments with it in actual blasting operations have yet reached the Author.

Various proposals to apply compressed air to the getting of coal have been put forward, among which was one by Mr. Samuel Marsh of the Clifton Colliery, Nottingham, to the practical development of which Mr. Ellis Lever devoted much trouble some years ago, but no really satisfactory results appear to have been attained with it.

¹ Tamping mixtures, containing hydrated crystallised salts, chalk, alkaline bicarbonates, ammonium salts, &c., have been proposed, some of them quite recently, with this object in view.

The considerable increase in volume which caustic or quick-lime rapidly undergoes during the slaking process (or its conversion into hydrate by union with water), was already many years ago regarded as a source of power which might be available in lieu of powder for the bringing down of hard coal; but repeated attempts to utilize it met with no practical success, until Messrs. Sebastian Smith and Moore, about six years since, made two important steps in advance. In the first place, by reducing freshly burned fat lime of high slaking power to powder, and converting this into cylinders by applying powerful pressure, they obtain the lime in an exceedingly compact form which enabled them to utilize the full diameter of a drilled shot-hole, and which rendered the material much less liable to deterioration from air-slaking than if kept in its natural state, in lumps, containing fissures. In the next place, Messrs. Smith and Moore apply the heat rapidly developed in the loaded hole by the slaking of the lime-charge simultaneously throughout its entire length, to the generation and superheating of steam on a somewhat considerable scale, whereby the force exerted by the expanding charge of lime is importantly supplemented.

The idea of compressing unslaked lime into cartridges appears to have been entertained by Messrs. Hughes and Jones three years before Messrs. Smith and Moore; but its practical development has certainly rested with the latter, and this is in great measure due to the ingenious, simple, and very efficient arrangement adopted by them for ensuring the application of water to the compressed lime almost simultaneously throughout the entire length of the charge. Mr. A. H. Stokes, therefore, in his comments on the Commission's estimate of the value of Messrs. Smith and Moore's plan of using lime, has scarcely done justice to his powers of appreciating the merits of such practically good contrivances as not unfrequently lead to the successful application of processes, or operations, the germ of which may have been for some time created, but has remained dormant for want of development in a practical form. There is much in the somewhat remarkable comments of Mr. Stokes, brought before the Chesterfield and Midland Counties Institution of Engineers, on the statements of the Royal Commission regarding the lime-cartridge, that would appear to merit close examination as emanating from one of H.M. Inspectors of Mines; but those comments hardly bear the stamp of dispassionate criticism, and it may suffice, in illustration of this, to mention that, when pointing out that the Commissioners, in their impartial examination into Smith and Moore's system of getting coal by

means of lime-cartridges, stated certain facts not favourable to its successful application under particular circumstances, Mr. Stokes thinks fit to preface the extracts from the Report by the words "the Commissioners themselves admit."¹

The Author, in company with other members of the late Commission, witnessed on two occasions a series of operations with lime-cartridges in the Shipley Collieries, Derby, where they have been in constant use since 1882. The preparation and charging of a number of holes at one time was expeditiously carried out, and the joint action of the holes in bringing the coal down in large masses was very satisfactory, the charges generally performing their work up to the back of the holes. The time occupied by the action of the lime ranged from ten to forty minutes from the time of wetting the charge, but the men were able to return to their work directly the coal had fallen; the latter was brought down almost entirely in large masses, and the work in such coal (the "deep hard" seam) as is met with in the Shipley Collieries appeared, from the figures furnished to the Commission, to be carried on with advantage in point of economy over blasting. The results which have since that time been obtained with the lime-cartridge in a number of English mining districts appear, on the whole, to have been favourable to the efficiency and economy of the system of working. Several collieries in Staffordshire and Yorkshire now employ the lime-cartridge, and the Author understands that it has also been in use in collieries in Lancashire and Nottinghamshire. That its application should not be attended with the same success in soft and in very hard coal as in massive coal of medium hardness is to be expected, and seams in which many fissures occur are not likely to be worked successfully by the system, as the force due to the generation of steam by the slaking of the lime must be lost in many instances.

The inconveniences attending the distribution, after the blasting operation, of the hydrate of lime, which retains feebly caustic properties, through coal, must no doubt be occasionally felt by miners, though it is difficult, in reference to the strong views of their serious nature by Mr. Stokes, to understand why they are supposed to be especially felt in damp mines, or why a material which bricklayers continually handle with impunity, and without the protection of their hands "by leather and rags," should be so violent in its action when it comes into contact with the miner's hands,

¹ Transactions of the Chesterfield and Midland Counties Institution of Engineers, vol. xv. p. 134.

as to necessitate the protection of the skin from being "eaten away."

It is essential that, especially in damp mines, the cartridges should be kept in tightly-closed cases until just before they are required to charge a hole with; but this is scarcely more inconvenient than the necessity for keeping explosives, under similar conditions, in their properly closed receptacles. Statements which are unquestionably exaggerated have been made regarding dangers attending the use of lime-cartridges. A so-called blown-out shot with lime causes the latter to be more or less violently scattered about in the vicinity of the shot-hole, and should men be in the immediate neighbourhood it is very possible that their eyes may suffer from such an accident, but there is no possibility of an explosion being brought about by the blowing out of the lime, or by any other circumstance which may attend the use of the lime-cartridge. A series of experiments made under the Author's directions at Woolwich Arsenal, with the object of determining the maximum heat developed in the interior of a lime-cartridge as applied in coal getting, and the direct measurement of that temperature in several ways, showed that its extreme did not exceed about 600° Fahrenheit, and was therefore insufficient to inflame a gas- and air-mixture, or to ignite any inflammable material with which the lime-cartridge might possibly come into contact in actual practice.

The conclusion of the Commission, that "in some coal-seams the lime-cartridge will perform work quite equal to that accomplished with powder, at no greater cost, and with absolute immunity from risk of explosions," was arrived at after very careful inquiry, and is well worthy of the attention of colliery-proprietors.

Before quitting the subject of the removal of coal and its adjacent strata by disruptive agents, a few words should be said regarding the means employed for firing shots in coal-mines. It is obvious that the efficiency of any measures adopted for diminishing the risk of accidental explosions, consequent upon the employment of blasting agents, may be counteracted to a great degree by igniting the fuze, employed in firing the shot, either by means of a lamp-flame, a match, or a highly-heated wire, or by a liability of flame or very highly-heated gases to be projected into the air from the open end, or to burst through the covering of that part of the fuze which projects from the shot-hole. It is satisfactory to know that the original makers of the miners' fuze, Messrs. Bickford Smith and Co., are now manufacturing a

special fuze for use in fiery mines, which, so far as the Author's experiments with it allow of his speaking with confidence, appears free from any liability to allow of the escape of fire from it into the air of the mine.¹ Some special forms of safety-lamp have been recently constructed, with arrangements for allowing the fuze to be inserted therein and ignited without risk, so that the application of fire or a red-hot body to the fuze in the open air may be dispensed with. Devices have also been constructed to be fitted like a cap over the projecting end of the fuze, and containing an igniting arrangement which may be set into action from the outside, and will prevent the escape of fire into the surrounding air.

The application of electricity to the firing of shots, with the development of which the Author has been connected since, in the days of its infancy, the subject was jointly pursued by Sir Charles Wheatstone and himself, has for a long time past been so perfected as to render the operation simple, safe, and, in the long run, but little more expensive than firing by means of the so-called safety (or miners') fuze. In addition to its safety, the firing of the shot being accomplished out of contact with air, and within the charge itself, it presents the important advantages that the operation of firing is performed at a distance and precisely at any desired time, and that it may be postponed at any moment should doubt suddenly arise as to the safety or expediency of carrying out the operation. It, moreover, eliminates all risk of a premature explosion, and, if a shot fails to be fired, it may at once be approached without risk. The application of electric arrangements admits, besides, of the simultaneous or the more or less rapidly successive explosion of a number of shots, at accurately predetermined intervals, by the adoption of very simple arrangements. The operations connected with electric firing are very simple, and the Author has found no difficulty in obtaining their ready execution at the hands of miners of average intelligence. For these various reasons, and while admitting that there are circumstances, such as the difficulties connected with electrical firing in wet mines, which preclude the possibility of a general adoption of this mode of dealing with shots, the Author strongly urges that the use of electrical arrangements for shot-firing in fiery mines should, as recommended by the late Commission, be encouraged wherever it is practicable.

One of the most important subjects connected with the pre-

¹ Since completing this Paper, the Author has had an opportunity of seeing a new and very efficient safety-fuze especially adapted for coal-mines, which has been devised by Mr. Alfred Nobel.

vention of accidents in mines still remains to be dealt with, namely, the necessity for devoting especial attention to the sufficient and safe illumination of roads and working-places in mines.

There is no subject connected with the working of coal to which, since the days of Davy and Stephenson, more study and ingenuity have been continually devoted than to the improvement of the miners' lamp. The history of the first development of the safety-lamp has been so frequently before the public that its discussion here would present no feature of interest. One important matter should, however, be referred to, relating to the employment of the historical lamps of Sir Humphrey Davy and George Stephenson, and the but little less popular lamp of Dr. Clanny, the three kinds of lamp which have been in general use in this country until very recently. In the very moderate ventilating air-currents to be met with in coal mines, for some time after these lamps were first introduced, and which but rarely attained a velocity of 5 feet per second even in the air-ways of a mine, while there was but very little motion of the air in working-places, these lamps were really safe. In recent years, however, the great improvements in the ventilation of mines have completely changed the condition of things in the mine-ways and working-places, as regards the velocities of air-currents there met with. Even in the stalls of pillar workings, air-currents having velocities of over 5 feet per second are now to be found, while in long-wall workings the air passes the coal-face often at velocities of 10 to 15 feet per second, and the currents in the main-ways frequently range in velocity between 20 and 25 feet. Conditions may, moreover, arise, such as, on openings being made between two air-ways, when lamps may be exposed to currents travelling at a rate of 30 to 35 feet per second. It has long since been demonstrated that these great changes in the velocities with which air travels in, at any rate, a large number of coal-mines, have deprived the Davy and the Clanny lamps of the quality of safety which rendered them valuable to the miner, because, if they are exposed for short periods to currents of air (charged with fire-damp) which are travelling at velocities now frequently met with, they are liable to communicate fire to the gas- and air-mixture which surrounds them. This had been demonstrated, at any rate in the case of the Davy and the Clanny lamps, before the experiments of the late Royal Commission, by the results of experiments with lamps carried out by the Midland Institute of Mining Civil and Mechanical Engineers at Aldwarke Main Colliery in 1883 and 1884, under the superintendence of Mr. C. E. Rhodes

and Mr. Joseph Mitchell, M. Inst. C. E., by other Societies, by Mr. Smethurst and by individual workers. The dangerous character of these lamps, as well as the liability of the Stephenson lamp to bring about explosions when exposed to powerful currents of firedamp mixture, was so thoroughly demonstrated by the earlier of the Commissioners' systematic experiments, and appeared at the same time to be so little known at the date of their experiments (1880) that they thought it right at once to direct the attention of the Secretary of State for the Home Department officially to the insecurity of these lamps. The action taken thereon by the Home Office led to the warning of the Commissioners being withheld from the mining public; but, during the Committee stage of the new Mines' Regulation Act, the effect of that warning, repeated in the final Report of the Commission, prevailed, and words were introduced into the General Rule relating to safe construction of miners' lamps, excluding "unprotected" Stephenson, Clanny, or Davy lamps from being embraced under the definition of safety-lamps. Those important words were struck out by the House of Lords' Committee, upon the ground, as stated by the defender in *The Times* of this action of the Lords (speaking apparently with official authority), that they were superfluous. The context of that rule, however, clearly shows that this was by no means the case, and the writer was evidently not cognisant of the fact that air-currents vary greatly in velocity in different parts of one and the same mine, so that, although an unprotected Davy lamp might be safely carried in "that part of a mine" where it was to be "for the time being in use," the miner carrying it might, in passing to and from that part with this lamp, have to traverse air-ways, where, in the possible event of an incursion of gas, the conveyance of the lamp might be attended with danger, on account of the comparatively high velocity of the air-current against which it has there to be carried. The rule, as it now stands, does certainly not guard against this possible great danger; while, if the use of unprotected Davy, &c., lamps had been prohibited, the only hardship incurred by their owners would have been the necessity for having them converted into *protected* lamps, which can be effected at a small outlay, and whereby they are changed from dangerous into comparatively very safe lamps. The clause adopted by the Commons would therefore certainly not have operated as a "most vexatious restriction upon mine-owners," as urged by the defender of the Lords' amendment; indeed, the alteration of the Davy to a protected lamp was long ago extensively carried out voluntarily

by some mine-owners who had very large numbers of that lamp in use.

The systematic experiments of the Royal Commission included trials of more than two hundred and fifty lamps in explosive gas-and air-mixtures, travelling at velocities which ranged from 400 to 3,200 feet per minute. The inflammable gas used was of three kinds: firedamp furnished by a powerful blower in the 9-foot Wigan seam at Garswood Hall Colliery; a copious supply of firedamp furnished by a blower in the sandstone, about 60 yards above the 6-foot seam of the Rhondda Valley, situated in Llwynypia Colliery; and illuminating gas manufactured in the Royal Arsenal, Woolwich. The majority of the experiments were carried out in a long model gallery, similar in construction to the apparatus used by the various other experimenters already referred to. Special arrangements were adopted for insuring the maintenance of a uniform gas-supply to the apparatus, and a thorough mixture of the gas with the air-current as they entered the gallery together. The preparation of the lamps for trial and the mode of taking observations were also made the subjects of careful arrangement, so as to insure that the results obtained with different lamps were strictly comparative.

While the latter portion of the Commission's lamp-experiments was in progress, at Woolwich, a large number of lamps of different kinds, sent in by competitors for a prize offered by Mr. Ellis Lever, were submitted to the same tests as applied by the Commission, and with the use of the same apparatus; as two of its members, Mr. Burt and the Author, formed also part of the body of judges, the results obtained were kept thoroughly comparative with the Commission's experiments, and therefore formed a very useful addition to the data available for study. It was difficult to bring those experiments to a conclusion, as, up to the very last, fresh specimens, which were either modifications of particular lamps already tried or lamps presenting new features, were sent in for trial. The results of these extensive experiments (including special tests of considerable severity which were applied to some of the most promising lamps) showed that at the time the Commission brought its experimental work to a close, early in 1886, many varieties of miners' lamps existed, which, when in thorough working order, would afford almost complete safety if carried even in a highly explosive atmosphere, moving at the maximum velocities ordinarily met with in the air-ways of well-ventilated mines. Some of the lamps even resisted currents passing at over 3,000 feet per minute during the brief periods for

which it was practicable to submit them to this severe test. At such high velocities very slight imperfections, which do not affect the safety of a lamp at moderate velocities, are likely to become sources of danger. On the other hand, the exposure of a lamp to currents of extremely high velocities is likely to be only of very rare occurrence and short duration.

When a lamp of the Davy, Clanny, or Stephenson type is introduced into a current of an explosive firedamp-and-air mixture, the flame is almost immediately extinguished, and the gas-mixture burns within the lamp. In some lamps, the air-supply to which is meagre, the inflamed gas-mixture sometimes also ceases to burn in a very short time, but as a rule it continues to burn until extinguished accidentally, or until flame is communicated to the explosive atmosphere which surrounds the lamp, either by some portion of the latter becoming heated to bright redness, or by the glass breaking, or by the flame being driven through the gauze from some accidental cause. In some kinds of lamps, such as the Stephenson under certain conditions, both the lamp-flame and the ignited gas-mixture are almost instantaneously extinguished. If this occurs at high as well as low velocities (which is very rare) such a lamp obviously ranks high in point of safety; but it does not of necessity follow that a lamp in which the gas-mixture continues to burn is unsafe. So long as no portion of its structure is raised to incandescence, or so long as the glass, if the lamp has one, remains intact, there is no danger attending the burning of the gas-mixture. For these reasons it is obviously of the greatest importance that the part of the lamp within which the gas burns should be protected from the mechanical action of the current.

A large number of the lamps of recent construction have, like the Clanny and Mueseler, glass cylinders, which form the lower portion of the case surrounding the lamp-flame. From the point of view of efficiency as illuminating agents, such lamps are obviously superior to others of the Davy and Stephenson types; but they are open to objection on the score of the uncertainty of safety which the glass presents, partly because the latter may become cracked from various causes, independently of rough usage, such as irregular heating or cooling, by the burning of the gas-mixture within the lamp in close proximity to the glass, or by the lamp-flame impinging on the glass when the lamp is tilted, the accidental dropping of water upon the heated glass, &c. In such cases the establishment of an aperture of sufficient size to allow flame to pass may occur at any time. The difficulty which may

be experienced in maintaining a thoroughly tight union between the ends of the glass cylinder and the metal bearing-surfaces is another possible cause of doubtful safety in lamps of this class. A too rigid closing up at those parts is liable to lead to the cracking of the glass, but if the joints are unduly loose, these are liable to become an obvious source of danger, which will be very greatly increased if the glasses are at all chipped at the bearing surfaces, or are not ground very fairly parallel. Washers should also intervene between the glass- and metal-surfaces, and the omission of them may give rise to danger. The experience of the Commissioners showed that washers of asbestos mill-board are far superior to those of leather or of india-rubber in point of efficiency and durability, and washers of that material have now come into very general use.

Numerous lamps have been constructed with double glasses, the air-supply, before it reaches the flame, being brought down the annular channel formed by the space between the two glasses, the possible passage of flame through which is generally prevented by the application of wire-gauze diaphragms. These lamps, when perfect, are very safe, but the inner glass is exceedingly liable to be cracked or fractured by the action of the lamp-flame, and in that case the lamp becomes altogether altered in character and is liable to explode. Moreover, the difficulty of putting the lamp together, so as to ensure its perfect safety at starting, is obviously much increased by the use of two glasses.

The safety-lamp of Belgian origin, called the Mueseler, attracted great attention not many years ago, and has since been somewhat extensively used in some English collieries, besides being the Belgian official lamp and used in other parts of the Continent. It is derived from the Clanny lamp by the insertion, into the gauze cage or cap, of a central conical chimney, which is supported by an attached annular diaphragm of gauze, seized between the lower end of the gauze cap and the upper end of the glass cylinder. When this lamp is burning, and in a vertical position, the air requisite to feed it passes, under ordinary conditions, through the lower part of the gauze cage, in through the gauze diaphragm, and down to the flame, the products of combustion escaping up the chimney. But if the lamp is tilted so that the heated gases and vapours from the lamp-flame strike upon the gauze diaphragm, instead of passing up the chimney, the feeding of the lamp with air at once takes place down the chimney instead of through the diaphragm, and as the products of combustion are then immediately carried down from the upper part of the lamp on to the flame, the

latter is extinguished almost directly, and more rapidly in proportion as the bottom of the chimney is closer to the flame. Hence the Mueseler lamp requires very careful handling to prevent its being accidentally extinguished, and this has prevented it from becoming popular in this country. Moreover, the high reputation for safety with which the Mueseler lamp was introduced to the English mining world was in a measure destroyed by the results of experimental observations before the Commission commenced its lamp-investigations. Even slight departures from the officially prescribed dimensions of the chimney in the Belgian Mueseler lamp (and in English-made lamps there have been considerable variations in this respect), will give rise to a complete difference in the behaviour of the lamp, consequent upon an alteration in the mode of feed of the air, and, while the Belgian lamps are, as a rule, extinguished almost directly after their introduction into an explosive current, others of the general Mueseler pattern have been found to explode readily, even if the current is only travelling at a moderately high velocity.

Reference has already been made to the importance of affording that part of a lamp, through which the gas-mixture is likely to burn if it is introduced into an explosive air-current, protection against the mechanical action of the current. The partial inclosure of the Davy lamp in a glass cylinder (as in the jack-lamp) is an illustration of this kind of protection, which has been recently afforded still more effectually by completely inclosing the lamp in a tin can provided with one or more windows. Again, the upper part, or gauze, of the Clanny lamp has been protected by a metal jacket, or *bonnet*, as in the case of Smethurst's and Ashworth's lamps, which are comparatively very safe, and of the Marsaut lamp, one of the very safest and most efficient of recent lamps, in which, besides the jacket or bonnet, the single-gauze cap of the Clanny lamp is replaced by two or three somewhat conical caps of gauze, fitting closely one within the other at their bases, and gradually separating towards their upper part. By covering the gauze cap of the Mueseler lamp with a jacket or bonnet, and arranging for the entrance of air through holes in the horizontal flange to which the base of the bonnet is fixed, it becomes almost impossible to get a gas-mixture to burn in the upper part of the lamp; it may, however, possibly burn above the gauze diaphragm, and in that case the glass is liable to become cracked. The Morgan lamp, which was one of the safest lamps submitted to the Commission, is of the bonneted Mueseler type, but presents several original points of detail.

The results arrived at, in experiments with safety-lamps, by the several Mining Institutes, by the Commission, by Mr. C. E. Rhodes, of the Aldwarke Main Colliery, by Mr. Marsaut, by the French Commission, by Messrs. Kreischer and Winkler and others, present many points of practical interest which it is impossible to discuss within the limits of this Paper; the Commissioners' experiments, which have, perhaps, been the most systematically pursued and studied, have demonstrated that, among many lamps exhibiting a high degree of safety, there were some which failed to be practically useful, on account of their becoming extinguished so readily as to require the greatest care in carrying and handling, while others failed on account of deficiency in illuminating power, and others again were of so complicated a structure, consisting of so many parts, that they were very difficult to put together in a safe condition, and to keep in working order. The Commission specified lamps by Morgan, Hann, Purdy, and Soar, as ranking high in point of safety and other good qualities, while four lamps more especially, namely, the Marsaut lamp, Gray's lamp, that of Evan Thomas of most recent construction, and the bonneted Mueseler lamp, combined in a pre-eminent degree the quality of safety, under all conditions of service, with simplicity of construction, and good illuminating power as compared with that of lamps hitherto in general use. Since the publication of the Commission's experiments, improvements or simplifications have been made in some of the varieties of lamps tested by them, and the Author has, from time to time during the past year, been requested to examine lamps brought forward as novel, some appearing to possess features of considerable promise, which, however, it has not been in his power to test. The Mining Engineers' Associations in different parts of the country, and such trustworthy experimenters as Mr. C. E. Rhodes, will, it is to be hoped, continue to pursue the valuable lamp-testing experiments which they have instituted, from time to time, before and during the work of the Commission, so that the merits of new lamps may be practically and impartially determined.

The provision of appliances for closing the air-inlets or outlets, or both, in bonneted forms of safety-lamps, must be alluded to as an additional measure of safety which can readily be supplied, and has already been provided in some instances, as in the bonneted Mueseler of Mr. Stokes, and the bonneted Clanny of Mr. Mercier. By such arrangements the lamp can be extinguished at once if there appears any danger of the glass being cracked by the burning

of gas within the lamp. Arrangements have also been devised for automatically closing the inlets and outlets of lamps, when a temperature in some part has been attained which is likely to lead to danger. The closing mechanism, in most instances actuated by a spring, is held either by a string, or by a wire or strip of readily fusible metal, which is applied in that part of the particular lamp likely to become highly heated. The burning or charring of the string, or the melting of the metal wire or strip, releases the spring, which brings the closing appliance into operation. In a new, and apparently very good lamp of Mr. Clifford's, a loose perforated diaphragm, one side of which consists of fusible metal, is placed over the gauze diaphragm, which closes the top of the air-shafts. Should this become heated, the melting of the fusible metal causes the perforations to close up, and, the current through the lamp being thus interrupted, the flame is extinguished.

The closing or locking of safety-lamps before they are issued to the miner for use, in some way which renders an attempt to open them difficult of success and easily detected, is a wise precaution against the temptation to smokers to get at the lamp-flame. Although it is stated that the practice of opening lamps has much diminished in late years, the not unfrequent carrying of matches into mines scarcely warrants the conclusion that the dangers involved by the exposure of a flame in mine-workings are yet generally recognized or sufficiently dreaded by many miners. Only on the 23rd of last September, a paragraph in *The Times*, referring to an explosion at West Cannock Colliery, in South Staffordshire, stated that "pipes and matches were found in the injured men's clothes, the regulations being thus violated," and "that the pit was rather fiery, only locked safety-lamps being allowed to be used in it."

Until comparatively lately, the mechanical locks, with which lamps were mostly fitted, were of little or no use as a security against the lamp being opened, because a very simple key could readily be extemporized for undoing them. Many attempts have been made to provide greater security by arranging for the application of a magnet or an air-pump to withdraw a bolt which secures the two parts of the lamp together, but it has generally been found that these bolts could be withdrawn, by a little dexterity, without those appliances. One which appeared efficient to the Commissioners, and could not readily be tampered with, was a magnetic lock by Wolf. Some locks are so arranged that the unfastening of the lamp draws down the wick, the flame thus becoming extinguished, but most of them are liable easily to

get out of order, so that they do not move the wick. A very simple and efficient lock has been recently devised by Mr. Mercier; it is in the form of a bolt, the complete withdrawal of which is necessary before the lamp can be opened, while its partial withdrawal draws a hood over the lamp-flame, and at once extinguishes it. In another lamp of quite recent construction, devised by Mr. Eeli J. Palmer, of Toronto, the unscrewing of the oil-reservoir at once brings an extinguisher over the wick.

One of the best and most simple means of preventing a lamp from being opened, and which has come into extensive use, is a rivet-plug of lead, by which two projecting sockets on the upper and lower parts of the lamp are riveted together, the oil-vessel being thus connected with the lamp. The two faces of the plug, after the riveting is completed, are stamped with some mark or letter, which is changed from time to time; unless the stamping is adopted, it would not be difficult to remove the plug and replace it without detection. The mode of applying the rivet-plug and the position where it is applied varies; thus, when used with Ryder's patent lock it is applied horizontally, which allows of the stamped ends of the rivets being easily inspected. The so-called "protector-lamps" are also supplied with these rivet-locks, although the additional security thereby provided is scarcely needed, as the particular arrangement of the wick-tube in the lamp, combined with the nature of the fuel used in it, renders any attempt to open the lamp without the extinction of the flame almost impossible. An objection to the highly volatile character of the illuminant used is, however, that its flame is so slightly adherent to the wick, as to be readily extinguished by a jerk; on the other hand, this sensitiveness of the flame is an element of safety, as, if an explosive gas-mixture enters the lamp the flame is often extinguished even before there is time for the gas to become ignited. The uniform light given by these lamps, consequent upon the nature of the illuminant and the construction of the burner, secures to them advantages in addition to those due to their comparative safety; on the other hand, the employment of so highly volatile a liquid as petroleum spirit, especially upon the somewhat considerable scale arising out of the use of a large number of the lamps in connection with a colliery, involves risks of accidents in stores and lamp-rooms, which necessitate the adoption of special regulations in its storage and use; hence it is to be regretted that the manufacturers should have deemed it expedient to give to the petroleum spirit supplied for use with the protector-lamps, a name which cannot be called otherwise than misleading,

inasmuch as the designation *colzaline*, under which it is sold, certainly would lead the uninitiated to believe it to be at any rate related to colza oil or rape oil in its character and properties, instead of being a very volatile and therefore highly inflammable spirit.

It has been already stated that some recent forms of miners' lamps, the construction of which secures a high degree of safety, present the serious defect of giving but little light. This is due either to the tortuous character of the channels through which air has to be supplied or the products of combustion have to escape, or to the great cooling action of the mass of metal through which the products have to pass away, whereby the circulation or draught necessary for the maintenance of a proper air-supply is greatly diminished. The light furnished by the Davy and Stephenson lamps, even when freshly lit, is so poor that the superior light furnished by the Clanny and Mueseler lamps gave these a great advantage as effective illuminants, especially as, after burning for three or four hours, they still furnish as a rule more light than the Davy or Stephenson lamps. One of the objects which have been aimed at, as very important in improving safety-lamps, is to increase the illuminating power, which, in the Davy and Stephenson lamps, is only equal to between 0.1 and 0.2 of a sperm candle when they are first lighted, or directly after they have been freshly trimmed; while, the Clanny and Mueseler lamps give, when freshly lighted, between 0.5 and 0.4 of a candle, which is very fairly maintained during a shift, with proper attention to the lamp. It is, however, scarcely matter for surprise that, for the reasons given just now, the illuminating power attained in new forms of lamps has very rarely exceeded, and not often attained, the results furnished by the Clanny and the Mueseler. The difficulties attending the achievement of any important improvement in the form of burner and of wick are obviously great, as any attempt to render the wick more suitable for the advantageous burning of the illuminant, and to introduce improvements in the trimming arrangements, have to be circumscribed by the conditions which safety dictates. The employment of flat and broad wicks, instead of the simple cylindrical solid wick of small diameter, has been attended with some improvement in the light-giving power with the use of suitable oil, but such wicks are apt to smoke, and the flames to fall rapidly in illuminating power. The Marsaut lamps, in which loosely-plaited flat thin wicks of 0.5 inch in breadth are used, have furnished the best results in this direction; although

their illuminating power appeared, from the Commission's experiments, to be little, if at all, superior to that of the Clanny lamp (the highest result attained was 0·7 candle, while other lamps gave 0·4 to 0·54 candle); but they were found to maintain a very uniform length of flame for a comparatively considerable time. In the photometric experiments of the Commission, the protector lamps of the Davy and Stephenson types (burning petroleum spirit, *i.e.*, "colzaline") gave more light than similar lamps of ordinary construction burning rape or seal oil, while this was not the case with the protector Clanny, Mueseler, and Marsaut lamps. The original luminosity was, however, much more uniformly maintained by them than by the corresponding lamps burning rape or seal oil; indeed, the luminosity of the protector lamps was often found to increase slightly with long-continued burning, which was probably due to the lamp reservoir getting slightly warm, and thus yielding a somewhat more copious supply of illuminant to the wick.

Comparative photometric experiments, made with lamps of one and the same description, burning different oils or mixtures of oils, the treatment of the several lamps and flames being carefully recorded, have shown that seal oil is unquestionably superior to good refined rape oil or colza oil in regard to the maintenance of the flame at a fairly uniform height, and therefore in regard to uniformity of light given during lengthened periods, without having recourse to trimming. The results of a series of experiments with mixtures of these oils, and of mineral (petroleum or paraffin) oil, in various proportions, demonstrated that an admixture of petroleum oil of a flashing point of about 80° Fahrenheit (Abel-test), and therefore a safe oil, with rape oil and with seal oil, in the proportion of 1 part by measure to 2 parts of either of the two oils, furnished (especially with seal oil) a superior illuminating agent for miners' lamps, burning uniformly and with very little charring of the wick, or separation of lamp-black. The experiments showed that the two constituents of the mixed oil appeared to be burned in equal proportions throughout the duration of the life of a lamp-charge, and as regards the practical question of cost, the very considerably lower price of petroleum oil causes this improved mixed liquid illuminant to be cheaper than the pure vegetable or animal oil. The Author was recently informed by the Messrs. Peace, of Tyldesley Colliery, near Manchester, that these results have been confirmed by practical experience.

The Commissioners direct attention to some points relating to

the condition and nature of the wick used in miners' lamps, which considerably influence the duration of efficient burning of a lamp. Thus they point out that the capillary action of a wick is much interfered with if it be tightly twisted or plaited, and if it fit very tightly into the wick-holder; that a wick should always be dried before a fire or in an oven shortly before use, as the free passage of the illuminant is impeded by the presence of moisture in the wick-fibre, and that, if a wick is used for a long time, or allowed to remain soaking in the oil for a long period, its feeding action becomes reduced by the deposition of solid or semi-solid impurities collected from the oil, so that it is conducive to the efficiency of the lamps to fit them only with short lengths of wick, and to change the wick frequently.

The admitted possibility of some injury, or defect of construction, or of the putting together, of a lamp, being so minute or difficult to discern as to escape the most experienced eye, and being yet sufficient to cause the lamp to be dangerous, renders the provision of some reliable means of testing a lamp in gas, before it is issued to the miner, a most important precautionary measure. The testing of lamps in gas, in some way or other, has been adopted here and there for several years past; but the Royal Commissioners, impressed by their own somewhat extensive experience of the great difficulty frequently to be encountered in detecting minute imperfections in lamps which have given rise to explosions, insist, in their final Report, upon the absolute necessity of providing a gas-test for safety-lamps at all collieries where they are in use, and of submitting every lamp to the test before it is allowed to be taken into the mine. They point out that such gas-tests as are here and there provided, although better than none at all, are not by any means trustworthy, and they give indications as to the nature of testing arrangements which in their opinion will afford satisfactory results. Unfortunately, the necessity for bringing their labours to a conclusion before they could devote sufficient time to all the numerous branches of their inquiry, precluded their carrying the subject of lamp-testing by gas to a definite practical issue; but there is little doubt that this important subject will be thoroughly worked out ere long by one or other of the associations, or individual experimenters, who continue to labour in the direction of increasing the safety and efficiency of illuminating appliances for mines.

When the late Commission entered upon its labours, some of the members looked forward, perhaps somewhat too sanguinely, to the

pleasure of recording, at no distant day, the successful application, in practical ways, of electricity to the illumination of mine-roads and workings. That it was only able, upon completing its Report six years later, to describe achievements which could scarcely be considered much more than the germs of the future utilization of electricity in these directions, may have been disappointing; yet it was evident, even then, that electric light had an important future before it in mines.

Its application to the illumination of the pit-bottom and the immediately adjacent portions of the mine-roads obviously presented no practical difficulty, while even this limited utilization of the light, combined with its employment at the surface and in the buildings attached to a colliery, appeared likely to secure advantages in regard to efficiency of illumination, convenience, and comparative safety. The first experiments on the employment of the light underground were carried out by Mr. R. E. Crompton at Pleasley Colliery, near Mansfield, in 1881; glow-lamps were applied in some parts of the road, and conducting wires were carried up to a working face, but the trials were not pursued very far. Attempts were made to apply the light where the work of cutting coal was proceeding, by connecting portable lamps with the main conducting wire (fixed against one side of the haulage-road) by means of light leads, allowing plenty of slack; but this arrangement proved unpractical, on account of the obvious liability of their injury by falls of coal or stone, and of men to get their feet entangled in them, to the probable damage of the wires, and injury or fracture of the lamp. Trials of a similar nature were made soon afterwards at Earnock Colliery, where glow-lamps were also applied to some extent along the roadway of the mine; but they were not continued for any great length of time. At Risca Collieries an extensive electric-light installation was established at about this time, and has continued in operation with very satisfactory results. Arc-lights are applied at all the screens and sidings, and glow-lights in the shops, offices, and cabins, as well as at the pit-bottom, and to a distance of 100 yards along the main haulage-road, and the work at these parts is now carried on to great advantage with the aid of this very effective illumination. The National Colliery and the Abercarn Colliery speedily followed the example of Risca, the lighting installations there adopted being counterparts of that worked out at the latter place; the Harris's Navigation Colliery has also, for some years, been provided with electric light to the same extent, both on the surface and underground.

The impossibility of guarding against injury or fracture of such light insulated wires as could alone be applied for connecting movable lamps, for use at the working places, with main conductors leading to the dynamo-machine at the surface, soon rendered it evident that the success in providing the miner with a safe and efficient electric light could only be attained by the production of a perfectly self-contained lamp, not too heavy or bulky to preclude its being carried about underground, and capable of maintaining a supply of light equal to that furnished by efficient safety-lamps, during the entire period of a working shift. When Mr. Ellis Lever offered a prize, in 1883, for the best safety-lamp, two or three attempts at self-contained electric lamps were brought forward, but they could not be said to have afforded any encouragement to the hope that some practical success in this direction was imminent.

The subject was, however, earnestly attacked by Mr. J. Wilson Swan, and, before the Royal Commission concluded its labours, Mr. Swan was able to submit a secondary-battery lamp, of sufficiently small and suitable dimensions to be called really portable, though considerably heavier than was desirable (it weighed between 9 lbs. and 10 lbs.); when freshly charged and fitted with a glow-lamp of suitable resistance, it gave a light which was maintained for several hours at between 2 and 3 candle-power, and still furnished a light of about $1\frac{1}{2}$ candle-power at the expiration of eleven hours. Since then Mr. Swan has made further improvements in this lamp, which, with its strong wooden cylindrical case and compactly-arranged storage cells, weighs now only about 7 lbs., while the power and duration of the light furnished by it are about the same as in the earlier form of lamp. The Author is informed by Mr. G. W. Wilkinson, of Risca, that the lamp has been modified in some of its details, from time to time, in accordance with what were found to be essential requirements, in the course of its practical trial in that colliery; thirty of them, supplied by the Edison-Swan Electric Light Company, have been in use at that colliery for three months, having during that period been employed in connection with every variety of underground work. When brought to the surface at the end of a shift, they were recharged with the aid of a simple charging table, in connection with the dynamo of the general installation, this operation being carried out by one of the lads of the colliery. The weight of the lamp was not objected to by the miners, and it was found to furnish ample light for all purposes at present fulfilled by

safety-lamps, up to the expiration of sixteen hours, although its brightness had become considerably reduced; at the expiration of the three months, the batteries did not afford any evidence of a diminution of efficiency, and although they were submitted to the rough treatment incidental to their employment on the haulage roads, no instance of fracture or cracking of the stout glass which incloses the small glow-light, nor of injury to the glow-light itself or to any part of the instrument, occurred during the whole of the trial-period. In fact, excepting the small expenditure of power in re-charging the lamps which, with a large installation like that at Risca, was of no practical account, the lamps cost nothing for maintenance; a mere trifle was expended in wages in their preparation for use, and in these respects they obviously compared most favourably with even the simplest kinds of safety-lamps. Mr. Wilkinson feels himself justified from this thorough practical trial in considering that, if the miners' Swan lamp can be supplied at a cost of even somewhat more than double the price of the most expensive efficient safety-lamp of latest construction, and will remain efficient for twelve months, it will repay its cost in that time for the reasons above given.

The London and South Western Coal Company, the Abercarn Steam Coal Company, and the National Steam Coal Company, have recently decided to have recourse to the exclusive use of these lamps in their collieries, and three thousand will shortly be supplied for that purpose.

Mr. Swan, who is continuously active in elaborating improvements in the general efficiency of the lamp, and additions to its value in coal-mines, has endeavoured to make a modification of it, for inspecting purposes, in which a gas-indicator forms part of the lamp. He succeeded in the first instance in constructing, upon the side of the lamp, a small form of indicator upon Liveing's principle, but has abandoned this in favour of a eudiometrical indicator, by means of which he hopes that an inspector will be able, in a very simple and expeditious manner, to ascertain whether the air in different parts of a mine is equal in purity to a given standard. The objections to the eudiometrical method of examining the air of mines have been discussed in another part of this Paper; a practical trial of some duration, underground, to which this addition to the Swan lamp will shortly be submitted, may determine how far those objections interfere with its practical value.

While Mr. Swan has attained the results just indicated,

others have also not been unsuccessful in approaching the fulfilment of the conditions essential to the production of a serviceable miners' electric lamp. Mr. James Pitkin has constructed a portable and efficient variety of secondary battery, and has made a near approach towards the production of a good miners' lamp. The results which he now attains in regard to light furnished, and maintenance of the light, are fully equal to those obtained with the Swan lamp, and the weight of the experimental lamps which he has constructed is scarcely greater than that of some of the more recent forms of safety-lamps, being between 5 lbs. and 6 lbs. An efficient reflector concentrates the light of the small glow-lamp used, so as to effect strong illumination in any particular direction in front of the lamp. The latter requires modification of construction in several essential matters of detail, before it can be considered a practically serviceable lamp, and the duration of its efficiency, under practical conditions, has still to be determined upon a sufficiently extensive scale; this is, however, already in progress at Tyldesley Colliery, where, by the kindness of Messrs. Peace, the Author and some other members of the British Association recently had an opportunity of seeing some of these lamps in use underground.

Several attempts had been made before the completion of the Royal Commission's report, to produce primary batteries of different kinds, in a portable form, of sufficient power to maintain a practically useful light for the purposes of the miner. One of the first to attain somewhat promising results in this direction was Mr. Trouvé, though the maintenance of power of the battery used by him was insufficient to serve any useful purpose underground. Mr. T. Coad submitted a primary battery lamp in 1884, which appeared to afford some promise of success, though neither the maintenance of power, nor the dimensions of the battery, constituted an approach to the fulfilment of practical exigencies.

The liability of an explosive gas-mixture to be fired by the fracture of an incandescent glow-lamp within it, was experimentally demonstrated at an early stage of the attempts to apply the electric light in mines. But the possibility of danger arising from the use of glow-lamps in mine-ways and workings has been reduced to the remotest contingency by the arrangements adopted in the Swan electric-lamp. The miniature tubular glow-lamps are very difficult to break, they are moreover hermetically inclosed in exceedingly strong and carefully annealed hemispherical glass covers, which are not likely to be fractured by very rough usage, and which

may therefore be considered thoroughly efficient protectors of glow-lamps. With a view to ensure absolute safety in connection with the use of the glow-lamp, Mr. Coad adopted the ingenious device of inclosing carbonic acid, under pressure, within the protecting glass. In the first instance, he proposed to fill the space within that glass with water, super-saturated with carbonic acid, and there was immersed in the carbonic acid solution an arrangement, whereby the circuit from the battery to the glow-lamp was to be at once broken if by the fracture of the glass the gas-pressure within was relieved. In a more recent form of his lamp which has been brought forward by Mr. Wilkin, a stop-cock arrangement is applied, through which the space inclosed by the glass shade may be charged with gas under pressure, by means of a small force-pump. When this pressure is established, the glow-lamp is set into action, and when the gas-pressure is relieved by the fracture of the glass or the opening of the stop-cock, the light is instantly extinguished. A similar arrangement has recently been brought before the public by Mr. Bailly. For the ingenuity of the idea much credit is due to Mr. Coad; but it appears to the Author doubtful whether, with the practically absolute security afforded by the very stout hemispherical glass-protecting shades, there is the least necessity for adopting this extra precaution, which, besides adding to the cost, detracts from the simplicity in preparation and use of electric hand-lamps.

Some special forms of primary battery have been proposed for the provision and maintenance of a light suitable for a miners' lamp. Thus Mr. Schanschieff has constructed a small sulphate of mercury battery, which he is applying to this purpose, and which has furnished, in regard to maintenance of power, more promising results than those attained by the batteries used by Trouvé and Coad. Early last year the Author had submitted to him by Mr. Blumberg some experimental lamps, in which the source of electricity consisted of a combination of small cells of Skrivanoff's modification of De la Rue's battery; the elements are zinc, and silver foil coated with chloride of silver, the exciting liquid being a solution of caustic potash. The smallest of the lamps submitted weighed only $4\frac{1}{2}$ lbs.; it furnished at starting a light equal to 1 candle-power; the luminosity fell only very gradually, and at the expiration of eight hours the light was but little superior to that of an ordinary Davy lamp. The Author has not had an opportunity of seeing the most recent form of this lamp, which is now, he believes, undergoing thorough practical trial; but the result quoted, which was decidedly in

advance of any other furnished by primary batteries, afforded great promise of a future for this variety of miners' lamp. The first cost of the battery itself may be somewhat heavy on account of the silver which enters into its construction, but as the value of the metallic silver, resulting from the reduction of the chloride during the operation of the battery, is always recoverable, the replacement of the elements is not costly.

The re-charging of the small primary batteries for miners' lamps is, of course, a somewhat more troublesome operation than the restoration of power of the secondary-battery lamps; on the other hand, the employment of the latter necessitates the provision of a generator. The great advantages secured, however, in connection with the necessities of a colliery by the provision of an electric-light installation, for general purposes, and for the efficient illumination of the pit-bottom and adjacent roadways, render their extensive adoption very probable. The average life of secondary-battery lamps has still to be ascertained, and the results accruing from the very extensive trials about to be made of them in South Wales will be awaited with much interest, as they will determine how far the original cost of these lamps, which at present will in many instances be prohibitive of their adoption, is compensated for by their durability, added to the very trifling expenditure upon their preparation for use and their maintenance. Meanwhile, there are now most substantial grounds for the confident belief that the problem of the successful and thoroughly safe application of electric light, in connection with every class of underground work, is in course of speedy and complete practical solution.

Although this Paper far exceeds in dimensions those originally contemplated by the Author, it has dealt, and that but imperfectly, with only the most important branches of the subject of accidents in coal-mines, their causes, and the means for preventing them, or, at any rate, for reducing their disastrous effects. The consideration of some parts of this important subject, such as accidents due to irruptions of water in mines, has been left untouched, and the results of much valuable work connected with the investigations of the causes of mine-explosions, which have during the last few years been assiduously and successfully pursued in this and other countries, have been discussed to an extent quite inadequate to their high importance. If, in reviewing those results generally, the Author has overlooked or failed to do justice to, the fruits of patient toil of zealous

workers who have laboured individually or collectively, with the object of reducing the perils to which a most important class of the community is constantly exposed, it is from no want of appreciation of their importance, but rather from an imperfect knowledge of all that has been accomplished in this direction.

To those who have thus earnestly laboured in this country, it must be a source of much satisfaction to know that, to some small extent, at any rate, the workers in British coal-mines are now about to reap the benefit of the knowledge which has been accumulated since the Mines Regulation Act of 1872 came into force. While the second part of this Paper was being prepared, the Coal-Mines Regulation Bill of 1887 has become law, and it will be cheerfully acknowledged, by all directly interested in the subject, that a great amelioration of the laws relating to the working and management of coal-mines has thereby been effected, even although those who have laboured to attain such amelioration may incline to the opinion that there are directions in which bolder innovations might have been accepted, with regard to matters directly relating to safe working in fiery and dusty mines, concerning which very definite conclusions were put forward by the late Royal Commission, based upon the results of comprehensive enquiry and experiments by its members and by many others.

That the publication of those conclusions has, however, borne good fruit, may be illustrated by reference to many clauses in the "General Rules" prescribed by the new Act, such as those which relate: to the provision of dumb-drifts in connection with ventilation of mines by furnaces; to the placing of mechanical contrivances for ventilation in positions where they will not be injured in the event of an explosion; to the provision of supplies of timber in suitable places underground, convenient to the workmen; to the regulations of a precautionary nature with regard to the preservation and manipulation of explosives, the charging of bore-holes, &c.; to the restrictions placed upon the use of gunpowder; and to the indications of the means to be employed for dealing with dry and dusty localities, and for blasting coal in such places where the use of powder is prohibited. The regulations which existed in the former Act regarding the employment of locked safety-lamps have been improved, and an important check has been given to the practice, which has prevailed in some places, of working with mixed lights, to which most serious attention was called by the Commission. The conditions which shall determine the safety of lamps to be used in mine-ways and workings are clearly laid

down; but the clause, as altered in the House of Lords, has, in the Author's opinion, and for the reason which he has given, been much weakened in regard to the protection from explosions afforded by it, by the omission of that part of the clause adopted by the Commons' Committee, which specifically prohibited the use of "*unprotected*" Davy, Clanny, and Stephenson lamps in any place in which there is likely to be any such quantity of inflammable gas as to render the use of naked lights dangerous.¹

The inspection of a mine, for the purpose of determining whether "*any*" inflammable gas is present, is still prescribed to be performed with a locked safety-lamp, which fails, in even the most skilled hands, to afford indication of the presence in the air of any proportion under 2 per cent. of firedamp, and even nearly 3 per cent., according to some authorities. The careful examination by the Commission, of the merits of a considerable number of firedamp detectors, showed that there was at any rate one description of instrument, easy of manipulation, by which small quantities of firedamp, even considerably below 1 per cent., can be rapidly detected, while another class of detector was likely soon to be sufficiently perfected for practical use with similar results. It is now generally accepted that even less than 2 per cent. of inflammable gas in the air of a mine, may, under certain conditions, constitute a source of considerable danger; moreover, it is admitted to be desirable that more accurate means of ascertaining the extent of contamination by firedamp of return air-currents should be provided than are afforded by the safety-lamp test. It is, therefore, to be regretted that some allusion to a probable future prescription of the use of trustworthy firedamp detectors could not have been inserted in the Act, as an inducement to managers of mines to familiarise themselves with such instruments as Liveing's Indicator, and to workers in these subjects to develop other testing-apparatus, which already present the germ of future usefulness.² Again, it was certainly most desirable to encourage the use of a gas-test in the inspection of safety-lamps, upon the necessity for which great stress was laid by the Commission, but no reference is even made to the desirableness of its provision.

¹ *Ante*, p. 64.

² In illustration of work which is being done in this direction it may be mentioned that the Count Montgela is obtaining promising results by combining an ingenious system of testing for gas and of underground signalling, elaborated by Mr. T. Shaw, M.E., of the United States, with improvements made by Mr. Sugg in the specific gravity gas indicators, referred to in Part I. of this Paper.

Taken as a whole, however, the "General Rules" embraced in the new Act, constitute a most important advance upon those of the Act of 1872; they cannot fail to contribute greatly to the diminution of the number and disastrous nature of coal-mine explosions and other mine-accidents, and their adoption constitutes a rich, and, it will be admitted, well-merited reward to those who have laboured long, earnestly and disinterestedly for the advancement of knowledge of the causes, and for the application of that knowledge to the prevention, of Accidents in Mines.

Discussion.

Mr. Bruce. Mr. G. B. BRUCE, President, said that the subject of the Paper was of great importance, and it was one on which the Author was a distinguished authority. The questions brought forward for discussion were the various causes of accidents in mines, falls in the roofs, dangers in hauling up and letting down cages in the shafts, and dangers from the variations in the barometric pressure and the presence of firedamp. The object should be to ascertain what could be done in the way of lessening those accidents from the roofs and the shafts, to decide what was the value to be ascribed to the difference of barometrical pressure at different times, how best to detect firedamp and discover the extent to which it was present, how far coal-dust added to the danger, what was the safest way of using explosives, what were the safest explosives to use, and the best means to be employed for getting coal when explosives could not be used; also to consider the nature of the lamps to be employed in mines. Those appeared to him to be the points chiefly requiring consideration.

Sir Frederick Abel. Sir FREDERICK ABEL said that his Paper, long as it was, presented so many imperfections, there being several subjects on which he might have touched, such as inundations in mines and other minor causes of accidents, that he wished to be allowed to make a few supplementary observations before the discussion commenced. He desired especially to refer to one important topic, because it might be alluded to in the course of the discussion, namely, the measures for dealing with casualties in mines. The Royal Commissioners were greatly impressed with the desirability of some system being instituted, whereby more effectual and generally applicable arrangements for dealing with casualties might be secured, and they pointed out two or three steps that might be taken by mine-owners and those interested in mines, quite apart from any action of the Government in the matter. They referred, for example, to the importance of having ambulances, stretchers and appliances ready for immediate use at every mine, and also of having centres where apparatus of a more special character might be kept, so as to be available at short notice in the event of serious accident; as, for example, the Fleuss apparatus, the employment of which rendered the user independent of the external air. They further pointed out how important it was that men should receive some amount of training in the use of simple appliances for saving life, or at any rate for dealing with accidents; and also in simple means

of dealing temporarily with wounds or other casualties. It was very satisfactory to note that in the Mines Regulation Act a clause had been introduced which prescribed that ambulances, stretchers, splints and other such appliances should be kept at mines; and also that no sooner had the Act been passed than the St. John's Ambulance Association, which did an important work in this country, set about actively to endeavour to introduce a system of training miners in simple operations useful in dealing temporarily with casualties when they occurred. He had referred to the Fleuss apparatus; he might also allude to others which had been brought forward from time to time to assist in the exploration of mines after accidents. There were different kinds of respirators, of which one or two of a very efficient character had been exhibited, notably one from Prussia, devised by Mr. Loeb, a respirator which enabled an explorer to go a short distance into a mine and remain there, this respirator being connected by means of a pipe with the external air. Mr. Fleuss had also furnished a very powerful and useful self-contained lamp of high illuminating power for exploring purposes; and, of late, electric lamps of comparatively high illuminating power, much higher than those which would probably come into use as substitutes for miners' lamps, had been brought forward, and would, no doubt, prove very valuable in explorations. He had in the Paper dealt with the subject of the great advance made within the last two years, he might say within the last twelve months, in the development of self-contained electric lamps for mines. As the latter part of his Paper was necessarily gone over rather cursorily, he might be permitted to refer briefly to the question of primary batteries. In reference to secondary batteries he had pointed out the great advance that had been made, especially by Mr. Swan, and the promising efforts made by Mr. Pitkin. He had also seen that evening a capital lamp of the same type exhibited by Mr. Urquhart, which was of comparatively small weight, and appeared to furnish a very satisfactory light. With regard to primary batteries, he had mentioned one or two that seemed to promise good results, notably that brought forward by Mr. Blumberg, the chloride of silver battery, and a single liquid battery in which sulphate of mercury was used, viz., the battery of Mr. Schanschieff. He had lately seen an important advance made by Mr. Schanschieff in the development of his battery, which combined very low internal resistance with high electromotive force; the experimental observations, which he and others had made with lamps in which this battery was used, indicated that

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it afforded very great promise of furnishing the miner with a light and comparatively cheap electric lamp. He had himself found that a lamp of that kind, weighing 5 or 6 lbs., gave over half a candle light at starting, at the end of five hours four-tenths, and at the end of ten hours (more than the time of an ordinary shift) it gave a greater illuminating power than an ordinary Davy lamp. Those results were very satisfactory, but no doubt they might be further improved upon. Both the Schanschieff and other primary batteries, such as the Eclipse lamp, were comparatively cheap in regard to maintenance; thus, the cost of the Schanschieff lamp just referred to had been found to be somewhat less than 1d. per hour. There was, of course, the one difficulty, that they had to be charged at every shift, but the charging could be reduced to as simple an operation as that of filling an ordinary lamp with oil, and he did not think that it would stand prominently in the way of the introduction of primary electric lamps. It was evident that the question of the application of electricity to portable lamps, for general purposes in mines, was on the way of being achieved with success.

Professor
Lupton.

Professor ARNOLD LUPTON observed that, after Sir Warrington Smyth, he thought he might claim to be the senior professor of mining engineering in the country, and for that reason he might be permitted to remark, speaking for Yorkshire, how much mining men appreciated the efforts made by the Author to bring before them, in a clear and comprehensive manner, many of those questions which could only be thoroughly dealt with by a gentleman of his great scientific attainments. When the Royal Commission on Accidents in Mines was appointed, there was considerable anxiety as to what the results would be. Practical men had been interfered with by legislation for many years; they had been constantly told by lawyers what they were to do, and what they were not to do, and when they heard the names of the distinguished men on the Commission, it was hoped that they would not recommend laws which, though well intended, would only have the effect of hindering their operations, without saving human life; because he could prove that some of the most popular prescriptions would not only cause injury to trade but increase the risks and loss of life. The result, he thought, had borne out their hopes. The Commissioners were a long time in making their report, but they most thoroughly investigated the question, and their report would stand as an interesting and valuable record of the researches of a period to which Englishmen might look back with pride. That was the opinion which he had formed, not because he agreed

with everything in the report (which it would be impossible for any active-minded man to do), but because he hardly thought it was possible to have produced a more exhaustive and valuable record. The Paper, he thought, condensed the report, if it added to it still further information. Referring to special points in the report, he desired to answer one suggestion of the President as to the means of diminishing accidents. He had the honour of making the suggestion before the Commission itself. He said, or intended to say, to the Commissioners: "Gentlemen, sit in permanence; let those men of scientific attainments, and practical mining engineers, be always sitting in London, so that any one who had an invention or idea might bring it before them; let it filter through their minds, and then let the information be made public." It would be much better to enlighten and guide the public in that way, than to order them. Mining engineers sometimes felt rather irritated when they were told by lawyers what they ought to do. Suppose that any member of the Institution were laying out a garden with beautiful flowers and shrubs, and Parliament by statute were to say "You shall plant daisies here, and mignonette there," and then, if the order was not strictly obeyed, there came a threat of prosecution, and if it was obeyed, the Government took all the credit of the garden to itself. That was how the matter stood with regard to some of the mining regulations. They were told to do this, that, and the other; but if they did not do ten times as much as they were ordered by law, it would not be practicable to manage the mine at all. They were told, for example, to put a fence round the fly-wheel; but they were not told to put a piston on the engine or a valve on the cylinder. The greater part of the work was left to their own intelligence; they were only instructed as to a few minute details, and were liable to be prosecuted if they did not attend to them. He hoped that so far as the intelligence of the meeting could affect the future legislation of the country it would be in favour of allowing mining engineers to manage their mines in the best way they could. The inspectors of mines used their great experience and position to guide or help the management. He considered they did great good; it was not the living hand of the Inspector to which objection could be taken, but the dead hand of a law about ever-changing mechanics to which he objected. The Author had alluded to the question of gas issuing from goaves. The danger of a goaf depended upon two things, the depth of the mine and the age of the goaf. In the case of a deep mine and an old goaf of large area, there would not be any hollows or places in

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Professor Lupton. which gas could accumulate. He had never seen a hollow in driving through old workings in the goaves in a deep mine ; it was only on the verge of the workings, where the goaf was new and the subsidence of the strata had not had time to crush and fill up every hole and interstice, that any opening could be found where gas could accumulate. With regard to the belt of goaf on the verge of the workings, the danger depended upon whether it was ventilated or not. In working mines, on the system of bringing back and having no air-road through the goaf, there might be a danger of a large quantity of gas accumulating, which, with a fall of the barometer, or some other cause, might come out and help to produce an explosion ; but if air-roads were taken through the goaf, and it was properly ventilated, there was comparatively little danger. He was pleased to observe the statement in the Paper, that the ratio of accidents in mines had been diminishing. This was true. In 1856 one life was lost for every 64,700 tons of coal raised ; but in 1886 one life was lost for every 188,800 tons of coal raised. Thus the death-rate was now only about one-third, a diminution most remarkable, and he thought in the highest degree creditable to the owners, managers, inspectors, officials of all degrees, and to the workmen. The amount of coal raised had very rapidly increased ; with that increase new dangers had arisen, and mining engineers had hardly acquired the amount of experience which enabled them fully to cope with all the dangers that were met with. Some accidents occurred through overwinding, through the cage being drawn up too far. Many mechanical engineers had set to work to devise means for preventing overwinding by disengaging hooks, so that the rope might be separated from the cage and not be drawn over the pulleys. Now, if he were in a cage suspended in a shaft, the last thing he should want to happen would be to be separated from the rope. Of course if he were just going over the pulley it would be a desirable thing, but he would rather go over the pulley than go down to the bottom of the pit. It had unfortunately happened that just when the safety apparatus was most wanted it had generally failed. When winding up at a slow rate it acted effectually ; but if it was wound up fast through some mistake of the engine man it was generally smashed to pieces. That showed how much a safety apparatus could be relied upon to prevent accidents. Many different kinds of hooks were used, and he thought that his observations would apply to all of them. Safety-hooks were not regarded as of high value by continental mining engineers, who preferred safety-cages, which in their turn were despised by

English engineers. Thus safety-cages were adopted almost universally on the Continent, while safety-hooks were almost universally adopted in England. That was a matter which should be taken into consideration by those who were inclined to pass regulations for the working of coal-mines. He thought an automatic contrivance, to regulate the speed of winding and stop the engine if it went too far, was much better than a disengaging hook; he had seen such an apparatus in France and also in England. He wished to ask the Author a theoretical question as to the pressure of gas existing in coal, whether he thought there was some connection between that and the depth of the mine. Of course the pressure could not be greater than was due to the superincumbent strata, and he wished to ask whether any measurements could be thoroughly relied upon to give the maximum gaseous pressure existing in the coal, considering that there were great practical difficulties in driving a bore in coal a sufficient distance, and then plugging it up so as to prevent the escape of any portion of gas. Allusion had been made in the Paper to the means of testing for gas in mines other than safety-lamps, such as Ansell's indicator. He believed he was present at the first practical test ever made in a mine with that instrument twenty years ago, and it was then a failure. It was evident that there was gas in the mine before the indicator showed it. He had carried a modified form of the indicator in his pocket, but had generally found it fail. The Author had alluded to the cheap way in which the electric fuze was now made. He had himself used thousands of those fuzes, or fuzes that bore the Author's name, which he had bought in London, and the only fault he had to find with them was their cost. If they could be reduced from 2½d. to ½d. each a great boon would be conferred upon the mining community. The Royal Commission attached great importance to the testing of safety-lamps before they were allowed to go into the mine. He had tested safety-lamps for many years, and the method he adopted was to take a lead pencil, push it through the gauze, and make a hole ¼ inch in diameter, so as to render it a thoroughly unsafe lamp, and then put it to the test; such a lamp often resisted a test in still gas. He thus tested the testing apparatus to see whether it would give him the assurance that he could not put an unsafe lamp into the mine after it had been through the apparatus. That was the difficulty. What he wanted was a testing apparatus that had been thoroughly tested, so that he could apply it to testing lamps. Until he had that he should prefer a safety-lamp that had been subjected to ten thousand practical tests, and then, when he knew the lamp was right, he

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Lupton.

Professor Lupton. would trust the eye and skill of the lamp-man and those who saw it put together, so as to feel sure that he had a practically safe lamp. With regard to a very important question, that of coal-dust, the Author had dealt with it in a masterly way, as he did all such questions. He believed that his experiments upon coal-dust, as well as those which he had reported in connection with the Prussian Firedamp Commission, had established without doubt the possibility of what might be called a pure coal-dust explosion; but as a mining engineer Professor Lupton would rely more upon the evidence found in the mines that had exploded. When he went into a mine and found an explosion originating in an intake air-road close to the pit, and that the explosion had gone through the intake roads, and not into the return roads, or working places where gas might be expected to be exuding from the coal, confining itself (though it had penetrated the workings of three or four seams) to the roads where gas would not be expected, and simply taking place where there was oxygen and coal-dust, he thought that was evidence going a long way in support of the pure coal-dust explosion theory. But the Author had asked what was the use in theorizing about a pure coal-dust explosion unless the air had been first analysed, and it was certain that there was no gas? Now there were places in mines where, if a chemist should say that he had analysed the air and found firedamp, he should be inclined to dispute the analysis. He should say "That coal was hewn twenty years ago, cut up into pillars, and roadways have been draining those pillars of gas for twenty years: there is an overwhelming supply of fresh air continually rushing along, and are you going to tell me that there is any coal-gas there? Because, if you do, let me ask how much coal-gas I may expect further in? If in 200 yards a main intake air-road will give an appreciable percentage, how much may I expect when I have gone through 20 miles of roads—not an uncommon length in one mine? How much firedamp may I expect in the return air that has passed through all that?" It was a simple question of rule of three. Allowing for the greater quantity of gas that came out of the workings nearer the face, it was not so simple; but the case was strongly in favour of the theory that there was no firedamp in the intake air-road close to the pit—not 1 per cent., not 0.1, or 0.01, or even 0.001 per cent., and if he came down to 0.001 per cent. he thought the Author would agree with him that if an explosion occurred, and if it was a question between firedamp and coal-dust, it must be a pure coal-dust explosion. He had recently studied the subject, and he had done so by the aid of information given him by the Author

and also by Messrs. Atkinson. Referring to the coal-dust question, he thought the mining engineers of the country owed a great debt of gratitude to Mr. William Galloway, mining engineer, of Cardiff, to whom in a great measure the bringing forward of the subject was due. His investigations, experiments, and persistent demonstrations had elicited a great deal of knowledge upon the subject. He had always in his own mind connected Mr. William Galloway with the coal-dust theory. He brought the subject before the Royal Society in 1876, and was the first mining engineer in England who drew attention to its importance. His investigations of many mines proved, he thought, almost beyond the possibility of doubt, that there had been large colliery explosions which might be correctly described as pure coal-dust explosions. Of course there had been many others which might be described as firedamp and coal-dust explosions, and there had been others which might be called pure firedamp explosions. But of late years most deaths had been produced not by pure firedamp explosions, but by firedamp and coal-dust explosions, and by pure coal-dust explosions. The means of laying the dust were now well ascertained and largely practised in different parts of the country. A short time ago he visited several collieries in South Wales, one of which was the Ynishir Colliery, managed by Mr. John James Thomas. Under his energetic management a length of about 3 miles of pipes had been laid through the workings, carrying water at a pressure of 70 or 80 lbs. on the square inch, in pipes $1\frac{1}{2}$ inch or 2 inches in diameter. At intervals of 25 or 30 yards he had stand-pipes, 4 feet high, with little jets sending out water in a fine spray, which were caught by air-currents and damped the mine. In that way the whole mine was damped, and when that was done the formation of dust was stopped. No harm was done to the roads by the water-spray; the duration of the timber was increased, the temperature of the mine was lowered, and the horses had a good supply of drinking-water at hand in the pipes. Even if the whole intake road was damped it was not likely that there would be much dust in any part of the mine. That plan was carried out by Mr. Archibald Hood at Llwynipia and at other collieries in South Wales. In some places there were not merely jets of water at high pressure, but of water and compressed air, the compressed air carrying water out in a fine spray into the mine, so that no puddles of water were formed which might cause injury to the road. This was the invention of Mr. Martin of Dowlais. There were several other ways of damping mines. Perhaps one of the most ingenious was that of Mr.

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Professor Stratton, in the Pochin pit, Tredegar Collieries. He turned the exhaust steam of an engine into the downcast shaft, and it had the effect of heating the air and damping it at the same time. It was well known that it was impossible to damp the air unless it was heated, and Mr. Stratton did both at the same time. He succeeded in damping the whole of the mine by putting steam into the intake air in the downcast shaft. It did very well in spring, summer, and autumn, but in winter it was not sufficient, because it would not heat the air enough, and in winter therefore the steam was supplemented by water-carts for laying the dust. This method of damping the air by steam was only applicable to mines of moderate depth, and consequently low temperature, say under 65° Fahrenheit, because it would make deeper mines too warm. The steam had done no harm to the roads or timber at the Pochin pit, and it made the mine much pleasanter. He would only say that it would be interesting to calculate what would be the probable effects of an explosion in a coal-dusty mine. He should measure the effect by the amount of oxygen in the mine, because he assumed that wherever there was coal-dust there was more than enough for chemical combination with the oxygen. He had made one calculation in the case of a large colliery which had exploded, and the combination of oxygen and coal-dust, assuming that all the oxygen in the air-ways where the explosion occurred was burned, was equal to an explosion of 90,000 lbs. of gunpowder, or of 4 lbs. for every lineal foot of the roadway. He did not pretend to say that was a trustworthy calculation; he merely used it as an illustration, and would rather put it interrogatively to the Author, or to some other chemist.

Mr. Tylden-
Wright.

Mr. C. TYLDEN-WRIGHT said all persons interested in mines, and in the working population, owed a deep debt of gratitude to the members of the Royal Commission, who had undertaken a Herculean task. The work had occupied them seven years, and it was a standard work for every one connected with mines throughout the country. The Commissioners had given an immense amount of detail which would be of great service, and absolutely without fee. He regretted, however, that the present discussion had not taken place before the Bill was considered in the House of Commons, because in that case the coal-owners would have been spared the trouble of combating many amendments that were introduced, which were certainly of an extraordinary nature. It was proposed to form "harbours of refuge" underground, which were to be hermetically sealed from the surrounding atmosphere, to be explosion-proof, and to be erected

in different parts of every colliery. It was also proposed that there should be two engine-men in every engine-house,—he supposed for the purpose of occupying one another's attention. Another proposal was that wherever gas was found in a mine, no underground furnace for ventilating purposes should be used for twelve months. The effect of that would have been to close absolutely the largest collieries in the country. Again, it was proposed, and he was sorry to find that the Author to some extent endorsed it, that all safety-lamps should be tested with gas. He might not be aware that there were hundreds of collieries in the country that had no gas-mains within miles of them, and how, in such cases, safety-lamps were to be tested by means of gas it was difficult to say. The public had to thank the common sense of the Home Secretary, and the calm judgment of the House of Lords, that coal-owners had been saved from the harassing legislation proposed by certain members of the House of Commons. The Bill was in some respects one of the most stringent ever passed, but in others it was thoroughly workable and practicable, notably with regard to the use of explosives in mines. Whereas there was formerly a great restriction put upon the use of gunpowder and explosives if gas had been found within three months, that time had now, without any risk whatever, been reduced to forty-eight hours, which was a very great improvement. No one understood the use of powder so well as the Author, who was *facile princeps* in everything connected with explosives; but he wished to tell him that for the purposes for which an explosive was wanted in mines no nitro-glycerine compound had been yet invented equal to gunpowder, and if he would devote his talents to the adoption of powder in some water-cartridge, he would do the greatest service to the coal-owning interest. With regard to safety-lamps, he had been greatly surprised and pleased to see the admirable collection of electric lamps produced for exhibition. They had their disadvantages, and safety-lamps of the old type must, he thought, always be used. One of the disadvantages was that they were all apparently of the nature of a bull's eye lamp, only throwing the light on one side, which he considered a fatal objection to a lamp underground in a pit. Again, the cost was, he thought, eight times that of an ordinary protected or unprotected Davy lamp, and what the effect would be of dropping them on the ground, which was a frequent occurrence in mines, he could not say; but he imagined that they would not long survive. Again, some of the lamps weighed 5 or 6 lbs., whereas an ordinary safety-lamp would only weigh from $1\frac{1}{4}$ to $1\frac{1}{2}$ lb. In that respect,

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therefore, he thought that the old safety-lamps were likely to hold their own for some time. They would also probably do so in other ways, because electric light was absolutely useless in testing for gas. One might walk into choke-damp with an electric light and fall to the ground without the light affording the slightest indication of danger, but with a safety-lamp the danger was at once apparent. The Author had raised a question on which he was bound to join issue with him with reference to "protected" and "unprotected" lamps. The House of Lords had met with very unmerited abuse for having altered the Bill, as it left the House of Commons, to the state in which the Home Secretary had originally drawn it. Nothing could be more definite with regard to the use of lamps than the present clause: "Wherever safety-lamps are used they shall be so constructed that they may be safely carried against the air current ordinarily prevailing in that part of the mine in which the lamps are for the time being in use, even though such current should be inflammable." The Author seemed to think that the part of the mine where the lamps were in use applied only to the working place where the man happened to work. His own view was that it was wherever the working man happened to take the lamp, and that the lamp must be perfectly safe in that particular place. He therefore thought that the House of Lords was perfectly justified in striking out the words which were hastily added in the Committee of the House of Commons, saying that unprotected Davy lamps should be prohibited. He thought it would be a great pity for the name of Davy to be under, however small, an amount of obloquy by being expressly prohibited in mines. He came from a district in South Staffordshire where the Davy lamp was looked upon as the most delicate and best practical apparatus for testing for gas. He would not say that it was the best for working throughout the shift in gaseous pits; but the condition of mines in that and some other districts was not generally gaseous; they only wanted examining by a safety-lamp, and then naked candles were used for the work. There was also a proposal, to which the Author had alluded, that "detaching hooks" should be enforced. He did not know how many accidents had happened from the want of them during the last fifteen years. In South Staffordshire not a single life had been lost from their not being used in working pits. As to the rest of England eleven lives had been lost from over-winding during the last year, of which ten were lost where detaching hooks had been employed. There was one other matter to which he would wish to refer connected with the safe working of mines,

and that was inspection. It might be thought that coal-owners were most unscrupulous, and workmen most incompetent to take care of themselves, from the number of inspectors supposed to be necessary. There were (1) the Government inspector and his staff of assistants, of whom he would wish to speak in nothing but praise; (2) Inspectors of weights and measures, who were compelled to test every machine at least twice a year; (3) Boiler inspectors, as provided by the Bill presented to the House of Commons by the President of the Board of Trade; (4) School inspectors; (5) Inspectors on behalf of workmen. The House of Commons altered the Bill so that any person who might have worked a month or so in a pit twenty or thirty years ago, might be sent by the men as often as they liked, to make this official inspection. He need not say that the experienced and trained managers of the pits, than whom a finer class did not exist, objected most strongly to taking such men through the most dangerous parts of the workings. The House of Lords did no more than bare justice to the colliery officials when they restricted the examination to actual working miners. He trusted mining legislation was now at rest for many years.

Mr. EMERSON BAINBRIDGE said he would name one or two points, which had been omitted by the Author, and there were one or two others on which he joined issue with Mr. Tylden-Wright. Reference had been made in the Paper to the increase of accidents due to a fall of the roof, but no cause for it had been assigned. He ventured to suggest that it was due to the fact that the seams which had the best roofs had, year after year, gradually become exhausted. The coal now produced in the various mining districts of the country from coal seams, had, in many cases, a roof which was not so good to manage as formerly, and therefore was more liable to cause accidents. In reference to the various means of breaking down coal, the Author had spoken of several mechanical wedges, but he thought he was right in saying that, in nearly all cases, the wedges referred to were not now used. As a matter of fact there was scarcely a single wedge, perhaps with one exception, that was now able to hold its own as a means of breaking down coal. The cause was much the same as that which had been the means of limiting the use of the lime-cartridge. The Author had warmly defended the lime-cartridge, and with good cause; but the fact that it was not used on a large scale, in more than about a dozen collieries, was rather against the idea of its being a success. The want of success was due almost entirely to the fact that it was difficult to get combined, a face of coal which would break

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down easily, a roof which would separate freely, and a coal which would break off well, conditions which were generally required, whether the wedge or the lime-cartridge was used, both being slow means of applying force to break down coal. There was one wedge now in use with great success in Belgium and the North of France. It consisted of two long steel wedge-pieces, which were placed in the shot-hole, the thick end inwards, and a third long wedge was driven between the two. The wedge was not employed in England on a large scale, but in France and Belgium it had been largely adopted. The objection to it was that whilst with the lime-cartridge or any other means of breaking down coal simple ordinary explosive force was applied, with the wedge a considerable quantity of "elbow-grease" was required, and a man had to take five or ten minutes in striking the centre wedge in order to get the coal broken down. No mention of that wedge, or of any wedge in practical use was made in the Paper. As to the question of safety-lamps, it might be a bold thing to say, but his impression was that there had been a great tendency to over-legislation, and to making restrictions upon means of mining which had never been proved to be the causes of any accident. In all the accidents of the last thirty years it would, he thought, be impossible to find five cases where an accident by explosion had been actually proved to be due to the use of such lamps as were condemned by the new Act. But in spite of the new regulation, which perhaps would cause nearly a million lamps to be altered, he was sure that every manager of a mine, who knew what a serious thing an accident was, would welcome the results of such important experiments as had been made by the Royal Commission. He was glad that the Author had passed a merited encomium upon Mr. C. E. Rhodes for his endeavour to test lamps, which he had done on a large scale in Yorkshire; but the moment a lamp was now put to a test, the idea was to have it tested at a current of 50 or 60 feet per second, which was an impossible velocity in any mine in existence. The ordinary velocity of an underground air-current was not more than 10 or 15 feet per second, and he ventured to assert that if a lamp would stand safely double that, or 30 feet per second, it might be considered, for most mines in the kingdom, practically and perfectly safe. It was not, therefore, necessary to fall back upon the elaborate designs of safety-lamps, some of which had been mentioned by the Author, and many of which were very complicated and costly. He might be permitted to give a sketch of a lamp which he was now endeavouring to bring out, and which had been on the previous day

tested by Mr. C. E. Rhodes, as a lamp of very simple construction, and which stood a 30-foot per second test by actual experiment. It was a bonneted Clanny lamp. First of all, the bonnet with holes in it at the top allowed the escape of carbonic acid gas; next, the gauge allowed the admittance of the fresh air into the lamp, the shield bonnet being a necessary addition. This lamp had been proved by experiment to stand a velocity of current of 30 feet per second, instead of exploding, as did the ordinary Clanny, at about 8 feet. The ordinary safety-lamp which stood severe tests had eight or nine parts, but the lamp he had designed was so arranged that the glass was fixed in the top of the lamp; the top or bonnet part unscrewed, so that when the top was removed the gauze could be examined and cleaned; the bottom part was also unscrewed to trim the lamp, and the glass was therefore left untouched, and could be left for six months, instead of, as was usual with the ordinary Clanny lamp, being removed every day. In speaking of the means of preventing accidents, the Author had referred to cages which were caught by self-acting catches, but he had failed to mention what appeared to be the most important invention of all. Perhaps he had not heard of this, as it was that of a working man who had been for twenty years trying to bring it before the mining public. Mr. Calow had invented a method of having a safety-cage so arranged, that the grip attached to the cage, which, if the rope broke, prevented it from falling down the shaft, only came into action when the cage actually became a falling body. In all other "cage-catchers," he believed that the catch itself was dependent upon the loosening of the winding-rope, but by means of a simple spring, Mr. Calow's was so arranged that the moment the cage became a falling body, the grips caught and stopped it. The Author had referred to substitutes for gunpowder, and Mr. Tylden-Wright had stated that no substitute had yet been found for gunpowder as an explosive which seemed to answer the purpose. It had been his good fortune during the last few months to come across an explosive of that character. In June last, he was engaged to go to Germany to report upon an explosive known as "roburite." He was told, that in Germany, there were some mines that had a stratum of 4 or 5 inches of gas constantly floating under the roof, that he might go down one of them, take this new explosive, put it in a ordinary blasting-hole, and fire it off, and there would then be no danger of any flame appearing! He need hardly say that he declined the experiment, but said that in a mine where there was no gas, he should be prepared to try it. He made the first experiments in July, for

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Mr. Bain-bridge. safety, in a quarry, where the roburite was tested under very trying conditions. He had first gunpowder, then dynamite, and then roburite, placed in small heaps, and covered with about $1\frac{1}{2}$ inch of sand. The experiment was tried at nine o'clock at night, and when the gunpowder exploded there was a very large illumination; when the dynamite exploded there was a large flame; but when the roburite was exploded by a detonator, there was not the least spark. He then proceeded to try the same experiment underground, and on the following day he placed, in the presence of twenty persons, a cartridge of roburite into a hole in the coal and the shot was fired, but there was no spark. He then tried, for the first time with this explosive, an experiment with a blown-out shot, which, as the Author had stated, had probably been the main cause of nearly all the most serious explosions that had happened in this country; and if anything could be done to prevent the disastrous effects of blown-out shots, one of the main causes of accidents by explosion would disappear. A charge of roburite was put into a hole, a small "stemming," of about $\frac{1}{2}$ inch, was put next to the charge, and a detonator was applied. The charge was then fired, and he had the satisfaction of seeing that the "blown-out shot" did not produce the least spark. If, therefore, roburite turned out to be, practically and economically, a good thing, it would prove a very important agent in future for mining. He also discovered in Germany that there were two other explosives, one named carbonite, and the other securite, which appeared to have similar action. The Author had spoken of carbonite with some degree of doubt, but Mr. Bainbridge thought that one or all of those explosives would be a very important means for putting an end to the risks attending the use of gunpowder, and to the danger of blown-out shots. A well-regulated mine, however, as a rule, ran very little risk of serious accident from the latter cause. At present, instead of leaving every man to fire his own shot, as was done years ago, a well-managed mine had a number of men called shot-firers, who attended to that matter and nothing else. They gained experience as to the size of the hole, as to the amount of gunpowder required, and as to whether the explosive was exactly regulated according to the work to be done; and, of course, if those things were well balanced there was little fear of blown-out shots taking place. As a point of economy it might be mentioned that whilst the lime-cartridge, the water-cartridge, and wedges required a hole about 2 inches in diameter, an explosive like roburite acted perfectly well with a hole $1\frac{1}{4}$ inch in diameter. Colliery managers in

Germany reported that in using this explosive, there was an increase in the quantity of large coal produced. Mr. Bain-bridge.

Mr. WILLIAM MORGANS stated that he was unable to agree with Mr. Morgans. the views of the last speaker as to the testing of safety-lamps. It was necessary that lamps should withstand higher velocities than the ordinary currents met with in mines, because they might be exposed to sudden outbursts of gas. Turning to the subject of explosions, if the manager of a colliery was wise, he would attach due importance to both coal-dust and firedamp accumulations in mines. By all means let the moistening of coal-dust be carried to any extent desired, but let not the danger of firedamp accumulations be overlooked, which, though rarely seen in working places, were often found in adjacent goaves or contiguous old workings, and unfortunately so by the sanction of the law. One speaker appeared to feel very positive that more explosions were due to coal-dust than was generally realized, but so far as Mr. Morgans could judge, it had become the fashion to apply the coal-dust theory too commonly. Not only had there been a disposition to subordinate the evils of firedamp to those of coal-dust, but the active pursuit of the coal-dust theory had engendered a disposition to ignore firedamp altogether. This had done harm by diverting attention from a long standing danger. It was to be hoped that the height of enthusiasm respecting coal-dust was reached in the case of the Altofts explosion. Firedamp was known to occur in that colliery, but the explosion was attributed to coal-dust alone. The official report afforded reason for considering that firedamp was the backbone of that explosion, and that it occurred mainly in the disturbed roof strata where gas was often found in cracks and partings over intakes, as well as in other ways. Those who believed in explosions of coal-dust alone must find some better example than Altofts, which belonged to the armoury of their opponents, because firedamp was given off in that colliery. As yet there was not a single example to be brought forward of a colliery explosion in any of the dusty workings in this country which were free from firedamp, notwithstanding that blasting was extensively carried on in them day by day. Consequently, explosions of coal-dust could not be regarded as anything more than supplementary to explosions of firedamp. Experiments might be pointed to in opposition to this view, but experience would be found arrayed against those experiments. The thanks of the mining community were due to Mr. Joseph Dickinson for recently taking a step to divert the pursuit of coal-dust extremes to a safer course. In his Report on the Udston Colliery explosion,

Mr. Morgans. he subjected the coal-dust theory (which appeared to have been ridden rather hard by some witnesses) to criticism, and suggested alternative views, giving firedamp its due prominence, and directing attention to the gas in the stoopings or goaves. On p. 19 of his Report, the following paragraph occurred:—"The mine being dry and dusty, and the coal a Splint coal of a highly inflammable kind, gives plausibility to the supposition that the explosion was aggravated by dust. The evidence, however, showed that the main roads were the most dusty part of the mine, and not the rooms. It was, however, in the rooms not cut through and least dusty that there were the greatest signs of coking, extending not quite up to the face, and not in the main roads, some of the principal coking being in rooms which were not at work." Notwithstanding that in one instance the danger of goaves had been made light of, the authority of many Inspectors of Mines, of the late Royal Commission and of the Author, was against this, and the reasons advanced as to their safety would have to be greatly modified to harmonize with facts and with experience. As regarded the ventilation of goaves, he thought the day had passed for appealing to that impracticable idea. To ventilate the inaccessible ramifications of goaves, caused by the collapse of the broken roof strata over the excavated parts of a thick seam, was a physical impossibility. What was euphoniously called the ventilation of goaves would be more correctly described as the aerating of goaves. Unfortunately goaves could be aerified and brought to an extremely dangerous condition; and it could be shown that in ordinary cases it was impossible, if once goaves were permitted to exist, to prevent them from assuming that threatening character. The most dangerous goaves were found in collieries where thick fiery seams were extracted and little rubbish remained to occupy the wastes; and it was in collieries answering to that description that the examples of the greatest explosions which had happened in this country must be sought. It was the practice of allowing the roof to be crushed down in large masses which was the great mischief. The fallen débris, by filling up the excavated plane of the seam and getting compacted therein, was very misleading in giving an idea that the goaves were closed, but the dangerous goaves were the cavities and ruins of the broken roof strata overhead and out of sight. Goaves were by no means confined to the plane of the seam. When the dislodged masses of roof strata were very hard, the interstitial spaces and arched cavities were a long time closing, and they formed gas-holding goaves, often many acres in extent,

bordering on the workings. These magazines of firedamp were Mr. Morgans. in direct communication with the colliers, not only at the edges of the goaves, but through many joints and fissures developed in the roof, in consequence of not providing it with adequate support in the goaves. The strain thus set up in the roof converted what would be a safe top into a dangerous one, and increased the accidents by falls, which were the most prolific cause of fatalities in mines. This was an important part of the goaf question which should be mentioned, although he was now more particularly dealing with explosions. The remedy for the evils consisted in adequately stowing the goaves with rubbish, but he would not here enter upon the commercial considerations beyond expressing his convictions that, apart from the saving of life and limb, great pecuniary benefit would accrue to the coal-mining industry and to the nation at large were the remedy applied. People must first be convinced that goaves were the cause of great disasters in mines. A good test of the existence of dangerous goaves in a fiery colliery was the effect of barometric changes upon the condition of the return air. Whenever a rapid fall of the barometer caused a great increase of firedamp in the return air, it might be concluded that the colliery was beset with dangerous goaves. This test had been incidentally confirmed in a Paper "On the Effect of Atmospheric Changes upon the Development of Firedamp," read before the Manchester Geological Society, on the 1st of December, 1885, by Mr. J. S. Martin, H.M. Inspector of Mines,¹ dealing with experiments made in the Gabriel colliery, near Karwin, in Austro-Silesia. But whilst the presence of dangerous goaves could be detected during a decided fall of the barometer, they remained an element of risk in a colliery under all barometric conditions, because gas might be suddenly expelled from them into the workings by a subsidence of the roof strata when the barometer was rising, or it might be exploded in the goaves by blasting elsewhere, or by some accident at any time independently of atmospheric conditions. The views referred to by the Author on the goaf danger appeared in a little book on the "Solution of Colliery Explosions." In it Mr. Morgans had endeavoured to strip the question of some of the glamour with which it had been surrounded; but the chief point in view was to direct attention to a factor in colliery explosions which aggravated the goaf danger, and had been overlooked. That was the dangerous character of cracks and fissures in the roof strata (1) as affording means of aerifying firedamp in

¹ Transactions of the Manchester Geological Society. Vol. xviii. p. 351.

Mr. Morgans. goaves; (2) as introducing unrecognized risks in shot-firing, whereby gas might be ignited in an unseen crevice at or near the seat of the cartridge or charge; and (3) as constituting avenues for the communication of the flame of an explosion from a working place or other point of origin to a goaf, and from one goaf to another over extensive ranges throughout the mine, without necessitating that the flame of the explosion should pass entirely through the ventilated ways and roads. The view thus indicated attributed the extension of the most violent and widespread colliery explosions to the firing of gas in the goaves and in the passages developed in the disturbed roof strata overlying the roads and workings of the mine. It accounted for the large falls often seen after explosions by the forcing down of the roof-beds, owing to the pressure of the explosions in their partings and joints. It explained the occurrence of conflicting blasts, or back explosions, bursting down into the roads at different points, and of apparently simultaneous explosions at parts of the workings very remote from each other, and other problems which could not be cleared up by the coal-dust theory. It suggested that the principal zone of the explosion was not necessarily in the plane of the workings, but oftentimes in the gas-charged goaves and roof strata overhead; and that the courses of the explosion, instead of being restricted, as by the coal-dust theory, to the ordinary roads, were frequently to be traced in the disturbed strata immediately above. One of the most conspicuous features of extensive colliery explosions had been the traces of violence, and of burning or charring, in widely-separated districts or portions of the mine. To account for the transmission of the flame from one district to another had been an object for investigation for a long time. Investigators appeared to have confined their attention to the overt ways of the colliery; while the dangerous system of communication opened by covert ways overhead had been overlooked. It was impossible to account for the presence of firedamp in most of those overt ways, since they were known to be abundantly ventilated. In this difficulty the coal-dust theory had been promulgated, and had done duty ever since. But it had certainly been accepted in some instances subject to the somewhat narrow view that an explosion must always pass through the roads, forgetting the fact that it might often pass above and cross over the roads. Dangerous goaves were not commonly found in thin seam workings, because the comparatively low wastes were usually so well stowed by the rubbish at hand as to prevent the wreck of the roof strata, and there was hardly a case on record of an explosion of mag-

nitide in workings of that description, however dry, dusty, Mr. Morgans. and fiery they might be. But workings in the thicker seams, where goaves were formed, owing to the insufficiency of the rubbish provided for stowing them, furnished the scene of almost every extensive colliery explosion on record, and all of the most disastrous and widespread explosions of the thirty-two on the Author's list had been confined to fiery seams of from 6 to 9 feet thick, or, in other words, to those precise conditions under which the most capacious and dangerous goaves were found to exist. Were not these grave facts which called for serious reflection? Was it not time that the investigation of the highly important goaf agency should be undertaken? It had long been neglected; it presented many features which demanded searching enquiry. Now that the Author had directed attention to the dangers of gas-holding goaves, it was to be hoped that the day was not far distant when they would be made a subject of thorough examination. At present, in some mines extensive surfaces of dust were watered whilst huge volumes of firedamp were warehoused. He readily joined in the expression of thanks due to all who had taken a prominent part in directing attention to coal-dust. Mr. Galloway had been more fortunate than many men in having his efforts freely recognized, and every-one would feel glad to acknowledge the capacity he had shown. But the labours of other workers must not be forgotten, of men on the French, Prussian and English Commission, and especially of the Author of the Paper now under discussion. In pointing out that the violence of explosions, where coal-dust was a prominent factor, would be far less pronounced than when firedamp was the chief agent, the Author had, he believed, supplied a very valuable key. Mining engineers could never lose sight of their indebtedness in the first instance to Faraday. Whatever experiments might indicate, actual experience had so far taught them that there was very little in the coal-dust question beyond what Faraday disclosed and put upon record, although its importance might have been in danger at one time of being forgotten. Had the goaf agency received a tithe of the attention which had been devoted to coal-dust, the prevention of accidents in mines would have made much greater progress.

Mr. SYDNEY F. WALKER said he was rather surprised to find that Mr. Walker. the Author had not referred to electric signals as one source of the avoidance of accidents. It was perhaps a humble one, but he believed that it had saved many a broken leg, and possibly a good deal of damage to the road. With regard to casualties it was

Mr. Walker. surprising that there were so few telephones in use in the working of mines. The amount of injury that a man received after an accident varied very closely in proportion to the time taken by the doctor in getting to him. If the telephone were at work, or could be attached to the existing signal wires, establishing a communication between the workings and the surface, a message could be sent that a man was hurt, and how, and a good deal of valuable time might thus be saved. With reference to the question of electric lighting, he had under his own superintendence twenty installations at different collieries, pit-bottoms, sidings and main roads; but in no case had they been taken to the face of the coal. In one instance the farthest lamp was a mile distant from the dynamo. He would only refer to the matter in regard to the question of cost. There was no difficulty in maintaining the lamps day and night, and the cost came out at from one-fourth to one-twelfth of the cost of gas. In the case of one-twelfth, the gas was made at the colliery. The main point dealt with in the Paper, in regard to the illuminating of collieries, was the lighting of the face of the coal. He thought that the eventual method of lighting the face of the coal by electric light would be similar to that adopted for the main roads, namely, from the supply mains. His experience, like that of every electrical engineer, was that no matter what light was displaced, immediately electric light came on the ground the user was not satisfied with the same amount of light that he had before. No matter whether a small candle was in use in a Cornish mine or a large argand lamp in a light-house, a great deal more light was wanted. That was shown, he thought, by the avidity with which the electric lamps exhibited in an adjoining room were taken up, on account of the extra light which they gave. But it was impossible to go far in that direction with a portable lamp, as the weight increased very rapidly in proportion to the degree of light. If, therefore, more light was wanted, and both the collier and the colliery owner would very soon appreciate the advantages of more light, it would become a question of providing it in another way. Then it should be borne in mind that at the same time the education of the collier was going on among the rising generation. There were science schools in the villages, and miners were getting accustomed to the use of electricity and electric lighting in all parts of the mines, and they would discover that by connecting the wires of a lamp, which possibly they carried in their pocket to their work, properly protected, they could have the light they needed, and that if the connection was broken they would have no light; when they arrived at that

point there would be no serious difficulty in working from supply- Mr. Walker.
 mains, properly and carefully fixed. Of course the grave danger
 would be the spark at the moment of connection; but it was by
 no means necessary that the final connection should be made in
 contact with the atmosphere. Many simple kinds of apparatus
 had been, and could be arranged for the purpose of making the
 final connection out of contact with the atmosphere. He might
 also mention that, from some experiments made by Mr. Mordey
 and himself, it had been proved that it was not a spark *per se*
 which ignited the gas, but a spark of a certain energy, and that
 that degree of energy did not exist at the end of a connection with
 a single lamp. As to the question of primary versus secondary
 lamps, he agreed with the Author that the operation of charging
 any properly-designed primary lamp would be quite as simple
 as the operation of cleaning and re-filling existing lamps. He
 thought, therefore, if a portable electric lamp came into use, that
 the primary lamp offered the greatest advantages in the present
 state of knowledge possessed by electrical engineers and by
 colliers. A secondary battery lamp looked more simple, but it
 was not so in operation. If there were five hundred lamps to
 connect in the colliery, there would be at least two thousand con-
 nections, the greater portion of which would be hidden. The case
 was not on all fours with the mechanical arrangement of emptying
 out liquids and putting them in again. Connections might go
 wrong at any time without anything to show it. Then again,
 how was the current to be obtained? The Author had suggested
 that it could be got from the existing dynamo at the colliery; but,
 in his opinion, to work from the existing dynamo would entail a
 considerable amount of complication, because it would entail a
 series multiple arrangement, which would be out of place at a
 colliery. He also most strongly condemned all switches, resist-
 ances, and automatic cut-outs and circuit-breakers for work in a
 colliery. Strength and simplicity were wanted, nothing else.

Colonel PAGET MOSLEY observed that it had been stated in the Colonel
 course of the discussion that the lime-cartridge system was quite Mosley.
 unable to get coal from where the parting between the roof and
 the coal was not a good one; or, at all events, where the circum-
 stances were not exceedingly favourable to the operations of any
 dialodging power. He had had on many occasions ocular demon-
 strations of the working of the lime in the collieries at Shipley,
 where the system was first brought out. The top was there of a
 particularly sticky nature; indeed, there was practically no part-
 ing at all in a great part of the colliery; so much so that, when

Colonel Mosley. wedges were formerly employed to dislodge the coal, after the wedges had dislodged as much coal as could be got by that means, there still remained a layer of 2 or 3 inches of very hard sticky coal, which had to be hacked off the roof with picks, but the lime got the entire seam down without leaving any coal on the roof. He regretted that Mr. Sebastian Smith, the inventor, was unable to be present, or he would have been able to give many more instances of the lime acting perfectly well in coal where the roof was of a very sticky nature. That had been evidenced also by the reports of managers in collieries where lime had been tried on many occasions. The system only wanted fair play, and the fact that it was not more largely adopted at present was perhaps in some measure due to the comments which were made by Mr. Stokes, one of the Government Inspectors, on the conclusions at which the Royal Commission had arrived with regard to the lime process in a Paper read before the Chesterfield and Midland Counties Institution of Engineers. Those comments were characterised by the Author as not being quite of a dispassionate nature; but ever since the system was brought out at the collieries at Shipley, Mr. Stokes had opposed it. He should have imagined that, as one of the Government Inspectors Mr. Stokes would have done all he could to encourage a system which, the Commissioners stated, would in some seams perform work quite equal to that done by powder, at no greater cost, and with absolute immunity from risk of explosion.

Mr. Hall. Mr. HENRY HALL remarked that the Author was not a mining engineer, but men outside the profession would often hit upon expedients that men inside it might fail to see. The principal points for discussion were, in his opinion, the method of lighting mines, and the method of blasting. With regard to lighting, he contended that too much stress had been laid upon the necessity of procuring a large amount of light from the lamps. The Author had recommended glass lamps, but these, he thought, were subject to many more dangers than the old-fashioned lamp which had gauze round the flame. A glass lamp was often broken by heat, and it might also be broken by being dropped on stone, or by anything falling on it. More than a dozen glass lamps would be broken in a colliery against one gauze lamp. It was pointed out in the Paper that falls of roofs would be less frequent if the men had a good light. He did not himself believe that such accidents ever happened from a collier having a bad light. The collier judged of the state of the roof by sounding it and listening, and he could do that whether he had a good or a bad light. As to

blasting in mines, if the water-cartridge was as safe as had been Mr. Hall represented, it would no doubt prove to be the greatest blessing that had ever fallen to the lot of miners. But there were certain points which needed some precaution. The water envelope was a weak contrivance, and it had to be used in a rough way. A thousand shots might be fired in one day by all kinds of hands; and if it was something that the colliers could manage to make dangerous, some of them would be sure to effect that object. With reference to dust, he did not think that any explosion had happened in a mine of importance where there was no firedamp. Still, there could be no doubt that the presence of coal-dust did greatly aggravate explosions. A good deal had been said about tests for gas. Certain instruments had been recommended as likely to be useful for that purpose. The difficulty that he and others had met with was not that they could not find the gas, but that when found they did not know how to deal with it. Even if much finer tests were available the difficulty would not be removed. He had used some of the apparatus suggested, but he had always to fall back upon the ordinary Davy lamp. He believed it was possible to test gas with a Davy lamp better than with any other instrument. Liveing's instrument had been recommended, but he was very unsuccessful in its use. It appeared that the handle had to be turned at a certain fixed speed, and if it was not turned at that speed the effect was not always constant. There was one point, which, he thought, might have been entered into more fully by the Royal Commissioners. They might have given some information as to the explosive force of certain quantities of firedamp. Officials found large volumes of gas here and there, but thought nothing of it, and said that it was not dangerous. It was difficult to say how much gas was dangerous. His own opinion was that a very small quantity, if it was really at the most explosive point, was very dangerous; but he had never come across any law on the subject.

Colonel J. D. SHAKESPEAR objected to the idea that coal-dust exploded; all it did was to get hot in the flame of a lamp and then, from being in minute particles, it might be driven through the wire gauze by the ventilating current, and if at a white heat it would ignite any firedamp present, whether in large or in small quantities. If coal-dust really exploded, coal-cellars would have been wrecked years ago. As to shot-firing its evil consequences were the concussion it gave to surrounding strata. With respect to the gunpowder and water-cartridge he contended that the gases, from the ignited powder, instantly overcame the extinguishing

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influence of the water which the inventor vainly hoped it might exert. Much ingenuity had been expended on electric safety-lamps, but he considered their intense brilliancy unsuitable to the hewer, since they cast a white beam that in the extreme darkness of the surroundings materially dazzled his sight. Rather than a dazzling speck of light close to him, a cutter of coal needed a diffused, soft light. On Tyneside, gas had been found to escape from the surface of the coal at a tension of 600 lbs. per square inch; and at Boldon Colliery, Mr. Lindsay Wood had found the tension to be 461 lbs. per square inch,¹ compared with which 50 lbs. per square foot, the force of wind in a hurricane, was a trifle.

Mr. Humble.

Mr. STEPHEN HUMBLE observed that reference had been made to an accident which was attributed to the failure of the apparatus connected with a detaching hook. At the Houghton Main Colliery, where the accident occurred, the depth of the shaft, from pit-bottom to the girders on which the catch-plate was fixed, was about 570 yards. The engines were 1,000 HP., and under steam forty seconds, and at the time of the accident the steam-brake had not been applied; consequently the force at which the cage went into the head-frame had been computed to be equal to a dead shock of 90 tons, which that part of the head-frame was not capable of sustaining; and although the hook detached the rope, the force of the overwind was so great as to tear away the bolts holding the catch-plate to the girders, which with the hook and cage dropped to the bottom of the shaft. Here the hook and catch-plate were found intact, and subsequently put into use again. Ten men lost their lives, but the accident was not attributable to the hook, and at the inquest the evidence proved that the hook acted perfectly well, and that the deaths occurred from the inadvertence of the engine-man in overwinding. At the neighbouring colliery of Messrs. Briggs, Son and Co., only a short time previously a similar case of overwinding had occurred, and there the hooks saved the lives of ten men; and only that morning he had received, from another neighbouring colliery, a letter which had been spontaneously written by Messrs. Pope and Pearson, stating that "during the six years we have had your 12-ton hooks in use at our Silkstone pit, where we work 1,000 tons per day, they have given every satisfaction. In a recent case of overwinding, the only one we have had, the action of the hook was all that could be desired."

¹ Transactions of the North of England Institute of Mining and Mechanical Engineers, vol. xxx. p. 221.

Sir GEORGE ELLIOT, Bart., stated that he had had something to do, in consultation with Lord Cross, with the constitution of the Royal Commission on Accidents in Mines. It was thought that at a time like the present, when intelligence and education and all sorts of practical skill were combined, it would be well to have a hybrid Commission, including what he might term philosophers and practical men. The Commission was accordingly constituted on those lines, and its members had worked together very earnestly; their Reports supplied a vast amount of information which was worthy of the study of every young mining engineer, and of discussion at every mining institution in the country. He might mention that he had taken part in the formation of the first mining institution in Durham, as well as the first mining institution in Wales. He had also suggested, in a Presidential Address in 1868, that the North of England Institute of Mining Engineers should be connected with the Durham University, in order that they might have the assistance of the professors there, and the many collateral advantages co-operation with a University would supply. He had also suggested an alliance between the great mining institutions of the country and the Institution of Civil Engineers, which he hoped the present President would do his best to bring about, mining engineering and everything connected with it being closely associated with civil engineering. He was unable to go fully into the great question of how to lessen accidents in mines, to which both as an employer of labour, and as an active public man, he had given much anxious thought; but as he had been a member of the Institution nearly forty years, had been a member of the Royal Commission, and had been long and largely associated with mines, he felt it a duty not to let the opportunity pass of testifying before his brother professional men the keen and abiding interest he took in this vitally important subject.

Sir WARINGTON SMYTH said he proposed to make a few remarks upon the Paper, taking the various subjects in the order in which they had been presented. He should indeed be acting the part of an unnatural parent if he had any quarrel with, or were to be unduly critical of, the Paper, seeing that the Author, being no doubt aware of the repugnance with which the greater part of the public looked upon Blue Books, had put their joint report into a readable form; and he hoped that much good might come of people taking up a book that was more convenient to read than the Blue Books, which they were so apt to thrust on one side. The Paper dealt with the whole of the subject which had been, after a very long period of thought and labour, brought before the Government as the Report of the Royal Commission. Some

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additional points, however, had been introduced at the beginning and in the course of the Paper, upon which alone he thought it necessary to say a few words. He agreed so thoroughly with the great bulk of the Paper, which was in fact mostly in the words of the Commission, that he had very little to say on those points which his friend and colleague had made so much his own, namely, explosions, blasting, and safety-lamps. But since reference had been made to the history of legislation on the subject of mines from the year 1835, he could not help suggesting that it had not been legislation alone that had done the great good which had been undoubtedly accomplished. He had observed, throughout the whole country, the totally different tone which now actuated those who performed their duties as managers of mines; and he found that the great exertions made by Mr. Nicholas Wood and others in the North, the establishment and active working of the Institutes of Mining Engineers, which began at Newcastle, and had since been carried out in almost all the important mining districts, had contributed quite as much, if not more, to the safer condition of mines than any legislation that had been passed. He saw that instead of holding aloof from one another, as people did formerly, instead of attending exclusively to their own occupation, men now met together to discuss all the difficult points, to make long series of experiments, and to discuss them in the most fair and friendly manner. He saw that they had been upon the right road, and that what had been accomplished in the Report of the Royal Commission was really contributing to confirm them in keeping that right road. He allowed there was much that the Commission had accomplished which was not new, but which others had been previously driving at, and he hoped that the authority conferred upon some of the statements made had proved a source of additional confidence and satisfaction in those Institutes, and in the men who composed them. There was also another remark which he desired to make in connection with the introductory part of the Paper—that whilst there was a very strong feeling entertained by a part of the public that legislation could do everything, that everything was to be referred to some Act of Parliament and some particular clause, and that a greatly increased Government inspection should be introduced for the purpose of rendering mines more safe, he must say from his own experience he held that nothing could be more pernicious or mischievous than the idea of substituting, for the daily and hourly inspection of the agents in the mines, any Government officials. When it was remembered what an extensive mine was, the miles of working that had to be gone through in order to examine

the whole place thoroughly, and that they had to be inspected every day by a series of, it was to be hoped, very competent persons, any notion of sending a Government official down even once a week was preposterous, and might produce the worst effects, in removing responsibility from those who were constantly amongst their men and placing it on outsiders. On what did the safety of a colliery depend? It depended from hour to hour, it might be almost said from minute to minute, upon the care and attention which were bestowed upon every portion of it by the subordinate officials, who had in the first place to go round the whole of the workings to see that they were safe, and then from time to time to visit the men at their respective places of work. A man might go through a colliery and find everything perfectly safe, and in five minutes afterwards there might be a blower bursting out, and the whole condition of things might be changed. Or some careless person might go through a ventilating-door and leave it open instead of shut, and in five minutes after the Government Inspector had been there, the whole place, instead of being safe, might be in a condition of extreme danger. It was the same with regard to lamps and many other particulars with reference to collieries. He held, therefore, that any idea of substituting an outside inspection for that daily and hourly care, which had to be expended upon the mine by subordinate agents, over-men, deputies, firemen, or whatever they might be called, was altogether out of the question. The Author had pointed out the satisfactory results, which had been obtained during the last thirty years, in the great diminution of accidents from most causes—from explosions and from accidents by machinery in shafts. Undoubtedly an enormous advance had been made in that particular direction, an advance which he thought was not exceeded in any other country. But from other points of view the retrospect was not so satisfactory. The Paper had stated the fact, that, of the average number of deaths which had occurred for several years past, 23 per cent. only were attributable to explosions, while over 40 per cent. were due to falls of ground or of the coal or mineral itself, and in other cases to falls from the roof or the sides made of other material, miscellaneous accidents forming about 35 per cent. The two last items had in one case been somewhat diminished, not greatly, and in the other case they hardly seemed to have diminished at all. He would therefore say a few words upon both. The accidents and the numbers of the deaths resulting from explosions and their consequences were extremely fluctuating. Of course, where at one particular colliery one hundred or two hundred men were carried

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away at one fell swoop, such an occurrence would very much disturb the run of the numbers. But the accidents from falls of ground, to which men were always subject, though they had some small fluctuations, kept at a very uniform level. The same thing occurred in regard to accidents from falls of ground in metalliferous mines, and also in the mines of Prussia, Belgium, and France. The Author had very properly opposed the contention of some persons, that causes of explosions having long been well understood should be readily guarded against. It was sometimes stated, both in and out of Parliament, and sometimes in speeches, which were to be greatly deplored from their violence and misstatements, that all accidents of that kind were preventable. He very much objected to that term. The same thing might be said with regard to all the accidents of life—"If you had avoided doing such and such a thing you would not have slipped down on the pavement, you would not have been thrown from your horse, or upset in a boat." No doubt there were many colliery accidents the origin of which could be traced and reasoned upon, but it was by no means the case that they were always preventable. There were so many ways in which the accidents took place, as shown by the annual reports of the inspectors, that although their origin might be explained they could scarcely be called preventable. For example, with the very best ventilation and the best safety-lamps, if gas broke out suddenly, accidents might be occasioned from various causes. There were safety-lamps for giving better light fitted and guarded with glass, but glass was a substance of a very uncertain nature, and, however carefully it might be fitted and examined, it might sometimes be so chipped that the flame might pass. Again, there were well authenticated instances in which a mere blow, by a pick on some quartzose material, had inflamed the gas which was present perhaps in small quantities. He did not assert that any very serious accidents had occurred in that way. There was, however, the analogous case of the sparks produced by the steel mill in former days before the general introduction of safety-lamps. Explosions on a considerable scale had actually been traced to the action of those sparks falling into a gaseous mixture from the action of the steel mill. And, if that were the case, the stroke of a miner's pick might in many cases, as it assuredly had in some, have been the cause of an explosion. He mentioned that matter because there was no working without a pick or a bar, and if they were capable of producing dangerous sparks only once in five hundred thousand times, that was a source of accident akin perhaps to others that might be mentioned. With regard to shaft

accidents, he was happy to agree with the Author that they had diminished in a most remarkable degree, and that the safety with which men were now conveyed to and from their work by means of machinery was really wonderful. It was, however, often proposed that the means at present in use should be supplemented by various other contrivances, and the subject of parachute- or safety-clutches had often been brought into notice. In the adjoining room various ingenious contrivances of the kind had been exhibited, and he supposed it might be said that there were not less than fifty or sixty different contrivances for that purpose. But, considering the rapidity of the winding now needed in the coalfields of the North, he had a strong sympathy with a number of thoughtful mining engineers who considered that, by adding an apparatus of that kind, they were merely introducing a new source of danger. Nor could he help recollecting that in two remarkable cases of late years there had been fitted to certain shafts apparatus of that kind, considered to be the very best that could be obtained. He was at the Botallack mine a few years ago, when the subject of lowering the men to their work and bringing them up again was discussed by the agents. He told them that he had very strong suspicions about the apparatus, although they showed him that they had an automatic contrivance, which was sure to clutch the rails in such a way as to make it certain that if the rope broke the cage would be sustained. The shaft was an inclined plane about 400 fathoms in length, and dipping at a steep angle. They then resolved, in order to avoid every sort of risk, to employ a man who should be thoroughly practised in dealing with the safety-clutch by means of his arm. He was to go down and come up with every batch of men. He was a very careful man, and he went regularly up and down with the apparatus, the rest of the "gig" being filled with miners. But on one unfortunate day in 1863 the chain broke and the cage fell away. The clutch was unavailing, the automatic apparatus did not act, the man who had his hand upon the lever which was to work it was either paralysed, or lost his presence of mind, or something else occurred which prevented its use, and all the men were smashed to death at the bottom of the shaft. Then there was another case which occurred only two years ago at Duke Hardenberg Colliery, in Westphalia, where no fewer than twenty-five men were dashed to pieces at the bottom of the shaft in consequence of the breakage of the rope, and the safety apparatus, which had been approved by everyone up to that point, failing to act. He believed that there were gentlemen present, who would bear him out in

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saying that they had not a sufficient trust in any of the varieties of safety-cages at present introduced, to make use of them, instead of adopting the ordinary plan of getting the best plant they could, and constantly looking to its being in good action. He need not refer to other causes, but he might mention that in several districts of England, to his certain knowledge, there had been a number of safety appliances of that kind attached to some of the collieries. Mr. Fourdrinier attached them to a number of collieries, which he saw about the year 1850, and more recently some ingenious kinds of apparatus had been applied at other pits; but it was a very significant circumstance that they were now all taken away. After owners had incurred the expense of fitting out pits in that manner there must, he thought, be some very strong practical objection to their remaining, if they had all been removed in a few years. The importance of a good light in collieries and other mines was a subject upon which the Author had properly enlarged. That mining engineers were not asleep about those matters might be seen from the various experiments that had been made, and the various lighting apparatus now on trial in different places. He would merely refer to one example. He had been struck, during the last two or three years, with the excellent progress made in the sinking of a very difficult shaft in the Foxdale mine in the Isle of Man. This shaft had been sunk about 206 fathoms, a large proportion of it being in exceedingly hard granite, so that it would have taken a very long time to have proceeded upon the old plan; air compressors were introduced, and the whole boring was done by machine borers. High explosives were used in the shape of tonite, and a telephone was carried down to give instantaneous messages to and from the men. Four electric lamps were used at the bottom and four at the surface, so that the men could go on night and day. After 10,000 lbs. of tonite had been used in that way, he was glad to receive a report from the agent to say that, in that long-continued sinking, there had not been a single accident. He thought that that said a great deal for high explosives, as well as for the completeness with which all the other matters had been carried out. In fact, the agent stated that as long as tonite had been used—a period of five or six years—there had never been a fatal accident. The Author had laid emphasis upon the different varieties of emission of firedamp. Upon that subject he would only say, that, whilst doubt had been cast upon the alleged emission by sudden outbursts occasionally overpowering all possible ventilation at the time, the Royal Commissioners, during the progress of their examinations and their

report, had had sufficient evidence to show, with the utmost clearness, that those accidents were unfortunately too common, having occurred over and over again, in connection with the increasing depth and other circumstances. He was himself not in a condition to throw the least doubt upon such statements, for he had once the misfortune of being at the bottom of a shaft in Abercarn mine. Fourteen persons were assembled at the bottom, when the floor suddenly began to heave. The men had only naked lights with them, but there was a supply of air from a compressor through a pipe a few feet above. After the first two or three heaves, there was a sudden upbursting of gas and water, violent enough to extinguish the whole of the lights. The kibble was signalled for instantly, it was lowered gently in the dark, and all the men were sent up in batches. It was found that, from the agency of the compressed air, in about an hour and a half the whole of the gas had been carried off; but there were marks in the bottom of the heaving up of the ground, while at the same time an advance bore-hole was being made 3 feet in depth below the bottom, and yet the gas and water had been able to burst up the shale floor. He was not likely to forget a scene of that kind, and he therefore attached due importance to the phenomenon, which was now vouched for by so many able and trustworthy managers. With reference to the remarks of Mr. Morgans as to the liability (about which not much was known) of open spaces existing sometimes, not for a very great height, but over a large area through the workings, the Royal Commission had paid some attention to that subject; but he might say in addition that there could be no doubt that it was the source of considerable danger. A few years ago a terrific explosion took place in the Risca pit. It was found that the explosion from a shot took place in the midst of a very strong current of fresh air, and those who had seen the place could not but adhere to the opinion that gas must have been about somewhere, that there must have been open spaces in communication by means of the cracks constantly made as the roof came down. There might have been such a communication as would have allowed some flame to pass through and thus ignite the gas. That, however, was a point, he thought, that required further investigation on the part of mine managers. With regard to blown-out shots, there could be no doubt that they had been the origin of a great many accidents of late years. Why should those shots be blown out? It arose mostly from mistakes in charging, or in applying them, or in not sufficiently cutting away the ground below or at the side to take fair advantage of the direction in

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which the shot was likely to blow. Such accidents were far less frequent in metalliferous mines. Why should that be the case? He believed it was simply because the men, instead of putting in a charge at right-angles to the face of the work, were accustomed to weigh carefully every place in which they had to put a hole. They considered the physics of the subject, the direction of the joints, the surface of the face and the nature of the material, and then they put in the shot to correspond with those joints, taking care, by means of a little heavy pick-work, to break away the rock in such direction as to be able to take advantage of the line of least resistance. He thought that in collieries sufficient attention was hardly paid to that point; and, therefore, if shots were to be carried on, as they must be in a great proportion of the collieries, the plan referred to by the Royal Commission of taking up the Author's original idea of blowing a mass asunder, by means of a comparatively small charge of high explosive immersed in water, promised to be of the very highest value in collieries as well as perhaps in some other mines. When it was called to mind that the Author brought forward that principle in the year 1873 before the Royal Society, and then experimented upon it in the presence of his friends and colleagues at the Garwood Pit, in Lancashire, and remembering the results produced as compared with the results of other charges, it was somewhat amusing to find people now quarrelling over the patent rights for what the Author had opened out for the benefit of the public. The experiments were not simply made in the sight of the few persons present, but they were published by Mr. Smethurst for the advantage of the public in the year 1881. The only satisfactory point about it was that, while people were disputing over their patents for some little modifications, so much attention was being paid to the subject, and that a long series of most valuable experiments had been made, especially those carried out in North Staffordshire with the assistance of Mr. Sawyer, Her Majesty's Inspector in the district. He thought, if the Royal Commission had done nothing else, it had done a valuable thing in starting and furthering that view which was likely to lead to so much good. As to the question of the lamp, he thought he must join issue with the Author in his onslaught, first on some of the lamps, and secondly on the House of Lords. There were many districts in the country where no gas had been perceptible from generation to generation. Why should lamps be forced upon people in such districts? Why go further (as had been done for some time past) than have a law that, in fear of any gas accumulating, a man should go round the whole of the works

With an ordinary Davy lamp in his hand, and test for gas. It had been objected that an ordinary Davy would not stand a current of explosive air; but in the collieries to which he had referred, which were scattered broadcast throughout the land, as in the Forest of Dean, South Staffordshire, and other districts, he was never noticed, and it would be very hard upon the people there to say to them: "You must not have a Davy or a Clanny lamp; you must take some new patent lamp capable of withstanding the effect of a strong current." In many of the collieries there was no strong current, but only just enough to bring the air quietly along. He thought that the present clause was a very fair one, that in no districts should lamps be used which had not the authorization of the Secretary of State for the Home Department. At the same time he was very glad to be able to confirm the statement, that there were now several lamps quite capable of standing against any current likely to be brought against them. Reference had been made by a previous speaker to the enormous pressure under which gas issued from the body of the coal, but he thought that that point was a little misunderstood. Besides having lamps capable of resisting any currents likely to be produced in a mine, it would also be desirable to have lamps free from the objections made to the more complicated ones, that they were not so convenient to test for gas as the ordinary Davy. The simple Davy had been very largely used, but he had been assured by a very competent authority, Mr. Lindsay Wood, that the Cased Davy, or Tin-Can Davy, the lamp placed in a cylinder in which a good part of the front was glass, was capable of testing for gas just as well as the open Davy, and that it was a thoroughly safe lamp for all ordinary conditions. He stated that his firemen were now using it, and that they could see the effect of the gas flame within just as well as they could with the ordinary Davy. At the same time he might mention that Mr. Sawyer had very carefully made a long series of experiments, which he had published, and he held that he could test for gas more satisfactorily by means of a Mueseler lamp than by any other. The glass of most modern lamps had been objected to by many old stagers, who were competent to give an opinion; but a still greater objection was that most of them were covered with a cap or bonnet, which gave a greatly increased heat to the lamp, and concealed everything above a certain plane in which the light was given out. He could not help thinking that that was a very serious matter. It tended to make miners wish to pull the cover off, as it prevented them from seeing what was doing

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in the lamp and whither they were going. They had to look to their feet to see that they did not run against a pulley, and at the same time to their heads to see that they did not strike against the beams. It was very important that light should be given freely on all sides, so that the men might be able to look both up and down. The question of the setting and drawing of timber was a most serious matter. It would be remembered that by far the greatest proportion of accidents happened under circumstances where protection could only be hoped for by setting the timber suitably and in good time. Lack of skill and promptitude, and a want of coolness and courage, were the circumstances under which many men lost their lives from not setting up timber at the proper time and in a proper way. But in collieries they stood on *terra firma*; there was a more or less horizontal plane to prop from, and everything was comparatively simple. When, however, those conditions were reversed, as in a metallic mine, where, instead of a solid horizontal ground, the deposit on which the working took place stood upon end, nearly perpendicular, and the men had to stand upon movable platforms, or upon thin pieces of plank, or some slippery ledge, then it was that skill, experience and courage on the part of the men were needed in an extra degree. It was under those circumstances that so many accidents occurred, which could not always be prevented. They were due to the fact that when men were underground they were subjected to the action of gravitation, tending to make everything fall about them. It was for that reason that he passed to the final subject, upon which he proposed to make a few remarks. It was impossible to begin that sort of experience too young. Unless men went early to mining, and got accustomed to use the pick and shovel and shooting-gear, they never became familiar with it; and therefore it was not to be wondered at that many working men now-a-days complained, amongst other things, that people were put in charge of a working place who were not capable of protecting either themselves or their mates. Men taken from agriculture, or other fields of labour, after a certain age never learned the thing properly, but were a source of constant difficulty and danger. When, therefore, he saw men like Mr. Pickard, the late miners' agent at Wigan, an excellent collier, and scores of others, who told him that they had gone into the pit at ten years of age, and had passed through all the successive stages of the work, he believed that those men, to say nothing of their thews and sinews, formed a much better class of men than those who were brought up to the age of fourteen or fifteen to hold nothing

heavier than a slate pencil or a pen. It was the constant wielding of their mining implements, and the skill acquired in setting timber, that made men cool afterwards and prompt to assist one another, and to act in such a way as might tend to reduce the number of accidents occurring from falls, somewhat in the same proportion as that in which they had been happily reduced, in other branches of mining over which scientific agencies could exercise a greater control.

Mr. A. R. SAWYER proposed, owing to the great amount of matter brought forward, to confine his observations to a few points only, namely, those to which he had lately given his greatest attention. As the Author had been good enough to allude to his book on "Accidents in Mines arising from Falls of Roof and Sides," he might be permitted to read a few lines from Chapter IX. of the book, pp. 97-98, which were of importance at the present time, when special rules were being made under the new Coal Mines Regulation Act:—"From many years' observation of the nature of accidents from falls of roof and sides, the writer is of opinion that the best way to reduce the number of these accidents is to establish rules for timber setting at every colliery, prescribing definite maximum distances, and other matters in connection with timbering and packing. All rules in connection with timbering must be based on the method of working, the nature of the roof and the inclination and thickness of the seams. These differ considerably, even at the same colliery, and at times in the same seam. These rules should be made by the manager, to the best of his ability, in conformity with the experience which he gains of the seam, and should be liable to alteration at any time in accordance with altered conditions or evidence of insufficiency. The enforcement of such rules would not only ensure regularity, but would indicate to fresh workmen the best and most approved manner of keeping themselves safe in seams in which they may perhaps have had no experience. Only maximum distances can, of course, be prescribed. It will frequently be necessary to set timber over and above the requirements of the rules. The erection of these additional supports must be left to the discretion and judgment of those immediately employed, who alone are cognizant of the momentary changes which the roof and sides present." It was therefore most important, as the Author had pointed out, that the men should be properly trained in the operations of timbering, and it was with a view to assist them in acquiring information, bearing on the subject, that he brought out the book. As many men, however, and these often well qualified

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Mr. Sawyer.

Mr. Sawyer. men, had been killed by falls owing to over-confidence as from ignorance, and he thought that such rules would restrain the over-confident, as well as instruct the inexperienced. If rules were thought too binding, the requirements might be presented in the form of advice, as had been done at the Dukinfield and other collieries. He thought it was idle to try to establish a connection between barometrical variations and colliery explosions. He was perfectly satisfied that a barometrical depression would cause gas to issue out of old workings containing it, but the gas need not necessarily be ignited, and so no explosion need follow. If, as used more generally to be the case formerly, this gas had to pass over a furnace, and was not sufficiently diluted by mixing with air before reaching it, an explosion would certainly ensue; so that the connection which it was sought to establish was dependent on another factor, namely, the presence or absence of flame. Two explosions, the causes of which he had had to inquire into, occurred at the same colliery within a short space of time from that very cause. A dumb drift was then constructed; and although gas still flowed out of the old workings invariably with a descending barometer, no explosion had since taken place, nor could any take place. Many explosions were due to causes which would have existed under any barometrical variation. Approaching barometrical depressions were soon detected by observant firemen, as outflows of gas were sure to show themselves at some point or other in most collieries, if not before, at least quite as soon as any barometrical indication. At some collieries the men were withdrawn when a barometrical depression reached a certain point. The quantity of air passing through the workings should possess a sufficient margin to cope effectually with an increased quantity of gas due to barometrical depression. He had noticed that some explosions, presumably caused by a blown-out powder-shot, had occurred when the barometer was very high and the thermometer very low. In a Paper on "The temperature and moisture of air-currents in Mines,"¹ he had pointed out, from observations made at the Dukinfield and other collieries, that the difference between the quantity of vapour in a cubic foot of air on the surface and in the return was greater the lower the temperature was on the surface, and he thought that on very cold days the air, by taking up moisture during its passage through the mine, owing to its temperature being raised as it proceeded

¹ Transactions of the North Staffordshire Institute of Mining and Mechanical Engineers, vol. viii. p. 8.

along the workings, might have a drying effect on the coal-dust Mr. Sawyer. and make it more susceptible to ignition by the flame of a blown-out shot. With regard to the supposed great sensitiveness of the Mueseler lamp, he would say that the Mueseler lamp was much liked by those who had become accustomed to its use, and the men who had once become accustomed to it were as wedded to it as they once were to the "Old Davy." This lamp could be tilted long enough to examine the roof by without being extinguished, and if preferred, he had found Mr. Brooks' reflector a convenient and effective adjunct for that purpose. He invariably carried his own Mueseler lamp during inspections, and had seldom known it to be extinguished under ordinary circumstances even in steep mines, although once in his hand he did not give it any further thought. The proper handling of it became instinctive. As a rule, especially in fiery mines, even Mueseler lamps should be bonneted, but the bonnets should be easily movable to facilitate an examination of the gauze by the fireman. With reference to lamp glasses, experiments made by Mr. Haines, Assoc. M. Inst. C.E., Secretary of the North Staffordshire Institute of Mining and Mechanical Engineers, and himself, showed that a cracked glass was not necessarily unsafe. In several of these experiments the lamp glass was cracked by the gas flame, which continued to burn within the lamp without any bad effects. Even where these cracks extended to all parts of the glass the pieces were kept in their places by the top and bottom rings, and in no case allowed the flame to pass, showing the necessity of well-fitting top and bottom rings. Though these experiments were reassuring, as showing that no immediate danger was to be apprehended from a cracked glass, especially when the crack was a perfectly vertical or diagonal straight, clean fracture, yet the moment a glass cracked the light should at once be put out, as a piece of the glass, if detached by a three-cornered crack, might fall out by a subsequent knock on the lamp. In these experiments lamps were also tilted at an angle of 45° . In the Marsaut and Clanny, with an ordinary flame, the glass cracked after from thirty seconds to one minute, whilst the Mueseler was extinguished before this could occur, which spoke in favour of the Mueseler type of lamp. With regard to the clause, in the new Coal Mines Regulation Act, concerning the conditions which shall determine the safety of lamps, he believed it would be found in practice to meet all the requirements of those who would have preferred a more specific prohibition of certain lamps. The sense in which it was understood in his neighbourhood was all that could be desired, and these

Mr. Sawyer. unprotected lamps were rapidly disappearing in all fiery mines. The safety of an unprotected gauze lamp, when it was carried against an inflammable current of the smallest velocity, depended entirely on the rate at which the person who was carrying it was travelling, and this varied much and could not be regulated. An explosion occurred very recently which was attributed to a Davy lamp, which was being carried by a collier, who was hastening in a direction contrary to that of an inflammable current, which at that place had a velocity of only 2 feet per second; so that this showed that an unprotected gauze lamp might not always be safely carried in an inflammable current of even the smallest velocity. He had made a Table, showing graphically the different sizes and shapes of "blue caps" produced by different percentages of gas in the air, and this was now put up in a conspicuous position at most of the North Staffordshire Collieries, and was serviceable in educating firemen and colliers with regard to the importance of even small caps. With regard to coal-dust; the explosion which fully convinced him that coal-dust, with possibly the faintest trace of firedamp, was sufficient of itself to cause an extensive explosion, through ignition by a badly-placed powder-shot, was the one which occurred at the Great Fenton Colliery in 1885. It was fully described in the Inspectors' Reports for that year. He had made numerous experiments with the water and the gelatinous-cartridges, and placed the result of his observations before the North Staffordshire Institute of Engineers so recently,¹ though these experiments began in May 1885, that it would be better for him not to discuss their merits again on the present occasion. He had come to the conclusion that if properly manipulated they were perfectly safe, but he thought it important to warn firemen and shot-firers that much depended on themselves to ensure perfect safety, and that this warning would become the more necessary later on, when the novelty of these cartridges had worn off, and when from their introduction fewer explosions occurred, thus having the effect of lulling them into a false sense of security. He saw these cartridges in use in the mines of North Staffordshire almost daily, and they had now been in use some years, with the satisfactory result that for that time such a dangerous coalfield had been exempt from explosions. The manner in which the gelatinous compound of Messrs. Heath and Frost's cartridge was blown out with a blown-out shot was interesting. From microscopical examinations made by Mr. C. M. Stuart, Fellow of

¹ Vol. viii. p. 266 *et seq.*

St. John's College, Cambridge, it appeared that the front portion Mr. Sawyer. of it was honeycombed with bubbles of hot gases, and was much dispersed or spread, but some portion of it, presumably from the back of the cartridge, was evidently only sucked out in small lumps, without spreading. It would be well to know whether, by the hot gases being so subdivided, much the same result was not obtained with this compound as with moss. A number of experiments which he had made with it pointed to this conclusion. With regard to the lime-cartridge, he would bring forward the experience gained by Mr. Bridgett, Manager of the Chatterley Coal and Iron Co.'s Collieries at Bucknall, which he could fully corroborate from personal and frequent observation. The Author had referred to the variable thicknesses and inclinations of the seams of coal in North Staffordshire. The Bucknall Mines had an inclination of 30° and a thickness of from 4 feet to 5 feet. Owing to their being in part extremely fiery, powder had been entirely dispensed with by Mr. Bridgett, and he had found lime-cartridges particularly suitable for getting the coal. Since the introduction of the high explosives with their safe surroundings, he had adopted them in one of the seams which was a particularly difficult one to get with lime, owing to the coal adhering strongly to the roof. In an ordinarily dry mine he had never heard of any complaints from handling the coals with the slight deposit of hydrate of lime, but the falling of the coal was accompanied by the distribution of some portion of it in the air in the form of fine dust. This was only a slight objection in a well-ventilated mine in which it was immediately carried away, but if the ventilation was defective it might remain suspended in the air for some time, and that was objectionable. He believed a person might be killed by the discharge of a blown-out lime-shot if he stood immediately in front of the hole after the lime was wetted. The dangerous moment was from one minute to two minutes after the lime was watered; if the stemming was strong enough to hold the lime then, it would hold it during the whole of the time that the action was going on. The heat produced during the slaking process was no doubt very great, but it was hardly sufficient to ignite gas. He had himself charged a hole in a very fiery colliery, with gas abounding in the place, without its being ignited, and this confirmed the Author's view of the matter. The cost of the lime-cartridges as compared with the new cartridges was found to be slightly less, when the greater amount of round coal produced was taken into account. In steep mines the districts were more circumscribed than in flatter mines, and as

Mr. Sawyer. the new cartridges required special persons to charge and fire them safely, and in some cases even to make them up at the face, more men would be needed for that work ; whilst with the lime-cartridges, which were manipulated by the stall men themselves, the cost entailed by special shot-lighters was dispensed with. Comparing the lime-cartridges with explosives generally, there was a constant temptation with the latter, as Sir Warrington Smyth had pointed out, to neglect the holing and cutting of the coal. It was sought to make the explosives do what should be done with the pick. This at some collieries conduced to make the men slovenly in their work, and it was from this cause that so many explosions had occurred from badly placed and fast shots, as he had pointed out lately in a Paper on blown-out shots.¹ With lime-cartridges there could not be such a temptation, as it was absolutely necessary to properly cut and hole the coal if it was to be removed by that means. In some seams it would then be found that, if properly cut and holed, the coals would come down without the intervention of the lime. Many accidents had occurred almost immediately after a shot had been fired, the roof or side having been shaken by the concussion of the explosive, whereas if the lime-cartridge had been in use, the piece of roof would, probably, have kept its place long enough to enable the workmen to remove the coal and set the necessary props. With explosives, props were also frequently knocked out, which was seldom the case where lime-cartridges were used, and this was particularly important with a bad roof. Danger from missed shots with explosives could occur from two causes : (1) where the mode of lighting the charge was by means of a fuze there was danger from returning to the shot too soon ; it was well known that a shot might go off from twenty to thirty minutes after it had been lighted, and it was also asserted that a shot might go off after a much longer delay ; and (2) all missed shots, whether lighted by means of a fuze or by electricity, were dangerous owing to the charge being necessarily and rightly left in the coal, according to the Act, until it was blown down by another shot, and then recovered by breaking up the coal. Where high explosives were used, a blow on the detonator might cause the charge to explode, and in the case of powder a spark produced by the tool might cause it to explode with fatal effects to those engaged in the work. An instance had occurred to his knowledge in which a powder-shot

¹ Transactions of the North Staffordshire Institute of Mining and Mechanical Engineers, vol. viii. p. 209.

missed fire, and the piece of stone which contained it was displaced by another shot. Whilst this piece was being split up the powder exploded and killed the unfortunate workmen. These were accidents which of course could not occur with lime-cartridges. He had recently made several experiments with Mr. Mould's patent coal-getter. There was no time to describe its construction further than to say that it was a hydraulic machine, the water necessary for its action being contained in the machine itself, and that, contrary to other such machines, its action was outwards. The experiments which he had witnessed had been satisfactory when the getter was properly applied, and he believed that the principle of its action was the right one. He considered it very important that none of these safe methods of removing coal should be discountenanced in any way, and that no one should be deterred by the difficulties which the want of practice in the first instance necessarily entailed, as these difficulties were frequently overcome by further experience. With regard to the prevention of explosions, he was particularly anxious that the lime-cartridge and mechanical coal-getters should receive all the encouragement possible, as they were absolutely safe. The high explosives, with their safe surroundings, though perfectly free from danger when properly used, were more or less dependent on human treatment for their safety, and though he was quite satisfied that the risk of an explosion was very greatly reduced where they had taken the place of powder, it would be desirable to have some other method of coal-getting to resort to, in case future experience were to show that these cartridges failed either from misuse or from a neglect of the ventilation, owing to a belief in their infallibility under any conditions. In conclusion he would express his sense of the indebtedness of the mining community to the late Royal Commission for its very arduous labours, and to the Author in particular for his valuable communications. The steadily diminishing death-rate in the North Staffordshire coalfield from one hundred and three persons killed in 1880, to twenty-six killed in 1886, could not but have been promoted by the stimulus given to the question of safety by the Commissioners' labours, and they were sure to bear still further fruit in future.

Mr. A. GILES, M.P., hoped it would not be allowed to go forth from the Institution that its members advocated the employment in mines of boys under twelve years of age. It would be remembered that an Act of Parliament was passed last session providing that no boy under the age of twelve should be allowed to go underground.

Mr. Bedlington.

Mr. R. BEDLINGTON said that some explosions might be due to other causes than those that had been mentioned. He remembered a case of several men timbering during the night, and a fall ensuing while they were at work, the concussion put out their lamps. The fireman coming up found the heading full of gas. He turned on one side and waited for some time, and then the gas disappeared. He went up to the men who were in the dark and found that there was no appearance of gas. If there had been an explosion in that case there would have been nothing to show how it occurred. He remembered another case in which there was a rupture making an opening in the floor. The gas came from the seam below in large volumes, and overcame the ventilation for a considerable time, but after a while the issue of gas ceased. So in many cases it was difficult to account for explosions that took place. There might have been a sudden emission, but there was no subsequent appearance of gas. As shown in the Paper the loss of life from explosions was 23·57 per cent.; and although the source of only one-fourth of the total loss of life, public attention was drawn much more to this class of accidents than to others, because of the great number of lives lost at one time. When an explosion took place the proportion burned to death was very small, seldom reaching 10 per cent. The great loss of life was due to suffocation. This arose from the air-doors being smashed, and the course of the ventilation being stopped through the greater part of the workings, the air taking the shortest course to the upcast. Where fans were used, they should as far as possible be fixed in positions that would not be affected by the rush of air after an explosion. In several cases they had been so damaged as to be useless for some time after an explosion. With ventilating furnaces the ventilating power was not much affected by an explosion. Assuming that the ventilating force was continued, the weak points were the air-doors. To lessen the risks from suffocation after an explosion, it appeared to him that the following arrangement might be adopted. Let the return air-way be at the top of the range, and the system of ascensional ventilation be carried out as far as possible. The splits of air should be as numerous as the total volume would permit of, so that each split was sufficient to properly ventilate the area assigned to it. The coursing of the air would then be as followed :—Passing from the downcast along the intake, No. 1 split would be coursed through the panel, or district, it had to ventilate, and then pass into the return air-way on the rise, the quantity allowed being regulated by a wall near the entrance to the return, strongly built in mortar, with an open-

ing of the proper size. The same thing should be done with the other splits. If an explosion took place in No. 1 split, and if the doors were broken within that area, the air would still pass through in the most direct course, and would continue in the other districts. At present, when an explosion took place, nearly all the ventilation was cut off from the workings owing to the smashing of the air-doors, and so the men were suffocated. In many cases the men were able to run some distance, but at last they dropped down. He was not yet convinced that dust alone would cause an explosion. If it did, explosions would be very frequent; but without contesting the matter he allowed that where much dust was about a gas explosion was aggravated by it. It was therefore desirable that the dust should be damped, and also for the reason that it was so injurious to health to breathe it. The temperature of the mine also would be cooled by the damping. A good system had been adopted of laying pipes from the pumping lift, along the level headings into the working places, with fine sprays at the requisite distances. The dust was thus damped and the temperature reduced continually without attendance. No doubt there had been many improvements in safety-lamps, making them safer in strong currents; but he thought that the electric lamp, such as Swan's, Pitkin's, &c., would be the safest of all to work by. At present they were heavy and expensive, in future he trusted these objections would be modified; yet the Davy lamp would be generally used for examinations by the firemen. The greatest loss of life arose from falls of roofs and sides, being 40·77 per cent. In the South Wales coal-basin there were dangers in working coal which were not met with, or not to such an extent, in other districts. He thought the roofs there were generally weaker than in most districts. The slips in the coal ran into the roof, and so caused a continuous break. Slants, threads, bells, and large nodules of ironstone also occurred. The principal seams of coal in South Wales ran up to a thickness varying from 5 feet to 9 feet, and the thicker the coal the more danger there was in working it. This was especially the case where the seam consisted of two or more veins with partings of shale. As the collieries became deeper the pressure increased, and it became more difficult to support the roofs, &c. The only means that could be adopted were careful timbering, double timber and props, with close packing of goaves to sustain the roof, holing props where the coal was being holed, and props against overhanging parts of the coal. The question of timbering had been well considered by the managers and workmen in Wales, and their opinion

Mr. Bedlington.

Mr. Bedding- generally was that it was best for the collier to timber and secure his working place, and not depend on deputies. Such was the evidence before the Royal Commissioners. A collier was always present during the working hours, noticing the varying condition of his working place, and could promptly do what was necessary to make it safe. Of course for general repairs timberers were kept. It was surprising that so much as 35·66 per cent. of the loss of life was due to miscellaneous causes. Overwinding was of rare occurrence at the Welsh collieries, and great credit was due to the enginemmen. At some collieries the appliances for the prevention of overwinding were fixed, but a majority of the managers thought it was best to depend on careful men, good machinery, and brakes. It was hardly necessary for him to speak of the great importance of good ropes, with a great margin of strength. Of late years mechanical haulage had been largely adopted, and there was now more liability to injury of persons than when the slow haulage by horses was employed. The man-holes, or refuges, were now 10 yards apart, instead of 20, and therefore it was hoped the danger would be lessened.

Mr. Combes. Mr. EDWARD COMBES, C.M.G., wished to point out a class of accident to which no allusion had been made either in the Paper or in the discussion, and his object in speaking was simply to invite the attention of the Author to the subject. In goaves or old workings large volumes of carbonic acid gas, or choke-damp often accumulated, and when any extensive fall of the roof took place, this deadly agent was, sometimes, by the consequent compression of the air, forced into the workings with fatal results to the miners, who were immediately suffocated. In some Australian mines, where no firedamp existed, this had been a fruitful source of accident, and had several times come under his notice. The question, he was aware, was one of ventilation; but it was rather a difficult one, inasmuch as with a rolling floor in a worked out part of the mine, the levels would vary so much, that in the lower portions the heavy choke-damp would find space in which to accumulate. Even when completely isolated, unless the brattices were made exceptionally strong, a heavy fall might cause sufficient pressure to blow them out and force the gas to positions where men were employed. This danger would escape the notice of any Government inspector. He therefore endorsed what Sir Warington Smyth and others had said with regard to the constant and careful inspection by responsible employees of mining companies, as affording better protection than the periodic inspection by Government officers.

Mr. Seymour. Mr. GEORGE SEYMOUR said he wished to speak rather as a

metalliferous than as a coal-mining engineer. Although the Mr. Seymour. Paper, on which the discussion was founded, was in every respect an admirable one as regarded accidents in collieries, the Author had, after all, only taken one side of the question, since he had made no allusion to the frequent accidents and grave loss of life which occurred from time to time in metalliferous mines. It was, of course, true that the number of men employed in the latter amounted to but a fraction of those employed in collieries, and that consequently the output from coal-mines was vastly greater; but, nevertheless, metalliferous mines had in days past contributed enormously to the wealth of the country, and still continued to do so, notwithstanding foreign competition; whilst the value of the metallic, as compared with the carbonaceous products, was in itself to a certain, although limited, extent an equalizing factor as regarded the relative importance of the output in such instances. The accidents in coal mines were, consequently, to-day, ton per ton, far more numerous than in metalliferous mines; but a hundred years ago this was not the case. The proportion of accidents in 1886 in English coal-mines from falls of rock was 48 per cent., and in metal mines 32 per cent., so that, after all, the difference was not very great. Falls of roof in collieries were naturally more numerous than in metalliferous mines, since in the latter instance the workings were more or less vertical, whereas in the former there was what might be termed an almost constant horizontality of roof, and consequently a greater natural liability to falls, attended frequently by most disastrous results. Whilst, owing to the generally vertical character of the workings, and the greater hardness and cohesion of the rock, such accidents were rarer in metalliferous mines; still they were not of unfrequent occurrence, and a few years ago four men were killed in Cornwall through an enormous rock falling upon them in the "winze," or underground shaft, in which they were working. The most fertile causes of accidents in metalliferous mines were, however: 1. Explosions, due to carelessness in tamping or injudicious handling of explosives; 2. Falls from ladders or man engines. The latter cause was one which rarely occurred in the deep American mines, owing to the custom almost universally prevalent in that country of raising the men by mechanical means. It should, however, be borne in mind that the workings in this case were planned and laid out *ab initio*, with a view to this method of development; whereas in the Cornish mines, many of which had been worked for centuries, the tortuousness and irregularity of the shafts rendered such a mode of haulage impossible, whilst the expense of

Mr. Seymour. sinking perpendicular shafts through hard rock to a great depth could not reasonably be entertained. It was not an unusual thing for a Cornish miner to walk 5 or 6 miles to his work, climb down from 300 to 400 fathoms on ladders, work an eight-hours' shift on a close end, and then climb back to the surface, carrying a heavy load of tools to be sharpened. Under these circumstances, the frequent occurrence of accidents of this description was not a matter for surprise. So long, however, as the present system remained, such accidents were inevitable. As regarded accidents in collieries, he would express his opinion that it was quite unnecessary, as contended by Mr. Morgans, that in order for a lamp to be safe, it should be able to withstand the velocity of current produced by an outburst of gas. Should such extreme safeguards be insisted upon, in all commercial undertakings, there would be a serious limit to enterprise. Seldom, if ever, had an explosion taken place when safety-lamps were used at the point and at the time of an outburst. In order to get an explosion with a safety-lamp—say such as Mr. Bainbridge had described—in the immediate vicinity of an outburst, three conditions were indispensable: 1. The outburst; 2. An explosive atmosphere caused by the explosion; 3. A lamp in the exact position where the speed of the expelled gas would strike it with velocity greater than 30 feet per second. It was exceedingly improbable that a combination of such conditions would occur simultaneously; and if colliery managers were expected to anticipate such coincidences, their attention would have to be diverted from objects far more conducive to the safety of the men and material under their charge. In conclusion, he wished to remark that, although the Author had devoted several pages to the question of gas-indicators, experience had demonstrated that these were of but little practical use. The inspection of all fiery mines was now virtually continuous, and the true check upon danger was such a constant examination of the different parts of the mine, as would render the existence of a small quantity of gas in any particular locality of very little if of any importance. The manager of the fiery mine would watch not so much for the returns which carried away the gas yielded by the mine, but would aim, by constantly and vigilantly watching the working faces, at conveying such a regular and sufficient current of air round the faces in question, as would cause the returns to consist of air containing a safe and regular quantity of gas.

Mr. Harries. Mr. HENRY HARRIES said that the Author had stated, that the Royal Commission had come to the conclusion that no general connection had been established between colliery explosions and

barometric changes; but in the preceding paragraph of the Paper, Mr. Harries. and in two or three other places he had observed that a fall of atmospheric pressure might be attended by an escape of gas to a dangerous extent. The discrepancy was only another instance of the differences of opinion existing on the question of the emission of firedamp in connection with barometrical fluctuations. Although, however, there was some confusion on the question, it would be conceded that the vast majority of both miners and the general public had great faith in the idea that explosions were experienced only with a low barometer. He had carefully examined the occurrence of explosions in connection with weather changes, not dealing with the variations at individual stations, as had been the custom hitherto, but taking into account the distribution of pressure all over the country and throughout Western Europe. He had taken European and American explosions, and instead of finding that they were experienced only with a low barometer, he had found that they seldom occurred at such times, but mostly under opposite conditions. A great deal of the prevalent opinion was due to the practice of newspaper reporters and writers, who appeared to be imbued with Mr. Buddle's opinion with regard to explosions, and generally ascribed disasters to a deficiency of pressure, whereas a little enquiry would disclose the facts to be otherwise. That, however, was not peculiar to this country, for he found in a leading French coal-trade journal the statement that firedamp explosions were almost invariably coincident with a marked diminution of pressure. A disastrous explosion at Quaregnon, near Mons, in March last, was commented upon in the Belgian press as having taken place with a very low barometer. Mr. Lancaster of the Brussels Observatory took up the question, and pointed out, in *Ciel et Terre*, how misleading the newspapers were upon the subject. The explosion was one of a series which took place during the passage of a large anti-cyclone from the Atlantic. The first explosion was in the Rhondda Valley on the evening of February 18th. Then on the arrival of the anti-cyclone in the south of France on February 23rd, there was the Riviera earthquake. On the morning of March 1st, when the centre of the anti-cyclone had reached Central France, the Chatelus mine, near St. Etienne, exploded, and ninety lives were lost. Then, moving northwards, the anti-cyclone was directly over the district where it was stated in the Belgian press that the barometer was low, whereas it was about 30·5 inches. It was not until a week afterwards that the barometer descended at Brussels to 30 inches. The Author had given a list of the principal explosions that had

Mr. Harries. taken place in the eleven years 1875–1885. Mr. Harries had gone through the list with the distribution of pressure for each day, and he had found that instead of following what was supposed to be the general rule, only six out of the thirty-two had taken place when the barometer was at 29·5 inches or below; in other words, only 18·75 per cent. occurred with a low barometer, while the deaths in the same amounted to 17·4 per cent. of the total loss. Even out of the six with a low barometer it was observable that three occurred when the barometer was rising rapidly. On the occasion of the great disturbance in January 1884, the barometer had risen 0·75 inch in twelve hours, when the Naval Steam Coal Colliery at Penygraig exploded, another, but slight, explosion taking place on the following day at Rowley, the mercury still rising. With the remaining twenty-six disasters the barometer ranged between 29·8 and 30·7 inches. Time did not permit of his entering fully into the details of each explosion, but he might mention that in the present year, when the Walker Colliery accident occurred, five weeks ago, the barometer was at 30·3 inches and rapidly rising. The Udston explosion, in another anti-cyclone, had been heralded during the increasing pressure by less disastrous accidents at Darcy Lever and Wigan. Last year three out of the four principal cases took place under similar conditions. The Pochin accident in 1884 occurred when the barometer was at 30·3, and on the next day in Belgium, when twenty lives were lost at the Wasmes mine, the barometer was at 30·4 inches. In the Leycett explosion of 1880, the barometer was at 30·65, at Seaham it was at 30·1, at Penygraig, December 1880, 30·4, and at Mardy at 30·7 inches. The increase of pressure which set in at about midnight of December 3rd, 1875, was accompanied by the New Tredegar explosion on the 4th, the Llan on the 5th, and Swaithe Main on the 6th. There did not appear to have been any disaster with the exceptionally low pressure of December 1886. Miners were after all but human, and, if they believed that accidents could only occur at certain times, they were apt to think that at other times they could do very much as they liked in spite of all regulations to the contrary. He had endeavoured, in a communication to *Nature* on the 8th of September last,¹ to explain this frequency of explosions with the prevalence of anti-cyclonic distributions of pressure, by the production of evidence from independent sources, showing that the enormous changes in the weight of the superincumbent atmosphere caused a straining

¹ Vol. xxxvi. pp. 437, 438.

of the earth's crust, to such an extent as to favour the issue of gas Mr. Harries. from the strata at a time when, theoretically, the escape of gas should cease. Professor G. H. Darwin had calculated that, with a range of 2 inches of barometric pressure, the surface was from 3 to 4 inches nearer the centre of the earth when the mercury was high than when it was low; but in the past few years the range of the barometer in this country had been close upon 3·75 inches, so that the level of the British Isles would vary by about 7 inches. It would be absurd to contend that a fall of the barometer did not affect the gas in goaves and waste places; the knowledge of the fact secured careful attention in almost every mine, and this might account for the small number of explosions which took place with low pressure. The worst disasters were those which occurred when the danger was least expected, and if the perusal of these observations could lead to a more careful study of the subject, and tend to reduce the liability to explosions, the time devoted to the present discussion would have been well spent. His remarks on the coal-dust question would be very brief. Much had been said on the subject in recent years, and all agreed that if the dust was an agent in explosions, it was most dangerous when it was driest. This being so, the question resolved itself into a consideration of the hygrometric condition of the atmosphere. Professor Lupton's remarks forcibly illustrated this, the moistening of the dust being comparatively easy in the warm atmosphere of spring, summer, and autumn, but very difficult in the cold dry air of winter. In Mr. Sawyer's Paper on "The Temperature and Moisture of Air-Currents in Mines,"¹ it was shown that dry and dusty mines were drier, and the dust more inflammable, on cold days than on warm days; and, where blasting operations were permitted, the experiments accounted for the increase in the number of explosions in the winter months. Now, a dry atmosphere, when it was most difficult to damp the dust, was a characteristic of anti-cyclones, and rendered the dust inflammable. Cyclones were accompanied by an excess of moisture in the air. This was an additional reason, therefore, for paying more attention to periods of high barometer than had hitherto been thought necessary. Taking all the explosions, great and small, it seemed that at least 75 per cent. took place with a high barometer, but he did not say that they were directly due to it.

Mr. WILLIAM COCHRANE wished to state the result of experi- Mr. Cochrane.

¹ Transactions of the North Staffordshire Institute of Mining and Mechanical Engineers, vol. viii. p. 8.

Mr. Cochrane. ments with which he had been connected in 1875 and 1876, when the first steps were taken in this country, after certain indications given by Mr. Vital in the "Annales des Mines," that small coal-dust, *per se*, was explosive without the possibility of admixture with carburetted hydrogen. Probably everyone would be impressed by the perusal of the Paper with the idea that a slight admixture of firedamp was necessary for an explosion. He did not know what would be called an explosion, but if, as in an experiment which he conducted with Professor Marreco, in January 1876, in the laboratories of the Physical Science College at Newcastle-on-Tyne, a detonation and the projecting of two small cast-iron weights from the top of a model drift, one going uncomfortably near his head, and the other across the experiment room, were to be called an explosion, it certainly took place, with the use of coal-dust alone, there being no possibility of having gas anywhere near where they were operating. A Davy lamp gauze formed the roof of the model drift, on which the dust coal was placed, a small Guibal fan supplied the air-current, and by rapping the side of the model drift the coal-dust fell, and a small pistol was fired into the drift. The result was an explosion, which ripped up the model and destroyed the Guibal ventilator employed to maintain the air-current. That showed that there was no necessity for the presence of even the smallest percentage of gas, which had been so much dwelt upon, and which the Author concluded was necessary.

. Sir FREDERICK ABEL's reply to the discussion will be found at the end of the Correspondence.

Correspondence.

Mr. Ashworth. Mr. JAMES ASHWORTH remarked that in general arrangement the Ashworth-Clanny lamp was similar to the Clanny lamps he sent to the Mines Accident Commission in May, 1882, known in the report as Clanny's Nos. 17, 18, and 19, which were the first completely shielded lamps tested by the commission; but the details of construction had been so greatly improved, that instead of the illumination produced by the wick flame being respectively 39, 64, and 56 per cent. of a standard sperm candle, the present lamp gave 79 per cent. as tested by Mr. Betley, of the Wigan Mining School. Attached to the screw ring which kept the glass in position, and at right-angles to it, was a thin metallic cylinder

reaching nearly up to the level of the top of the wick-tube, and Mr. Ashworth. perforated by four holes at its base; the top of the oil-vessel was made of tin or some metal which was a bad conductor of heat. By this arrangement of parts air entering the lamp was brought down the combustion-chamber close to the side of the glass, through the holes in the new ring and over the top of the oil-vessel, thus keeping both the glass and the oil-vessel cool, and also supplying an air-feed to the flame in the best way to secure perfect combustion. The Ashworth-Mueseler, A type, was a combination of his gauze chimney Jack-Davy lamp (called Ashworth No. 2 in the Mines Accident Report), and his shielded Clanny. Its principal novelty was in the substitution of a chimney, consisting of a slightly conical gauze cylinder with a truncated conical metal base, to which this gauze and the horizontal gauze disk were attached, for the metal chimney of the standard Mueseler. Besides being a safer form of chimney, its construction enabled him to increase the illumination of the wick flame, and to reduce the liability of the lamp to become suddenly extinguished when thrown on one side. The B type only differed from the A type in being provided with a second shield (No. 4 of the Mines Accident Report) placed between the outer one and the cylindrical gauze, perforated near its base with a row of inlet holes, and having a conical outlet. The outlet was gauged to permit the products of combustion to escape easily under normal conditions; but when firedamp exploded or burned within the lamp, the outlet was insufficient, and the whole of the interior of the shield became so full of carbonic acid gas, that the inlet air was fouled and all light within the lamp was extinguished at once. This type had been tested by Mr. Rhodes, of Rotherham, by Mr. Morgan, with his blow-pipe apparatus, at a pressure of $1\frac{1}{2}$ lb. per square inch, and lastly by Mr. Clifford, in a horizontal current of upwards of 100 feet per second, without any failure. For officials and firemen, this type of lamp was furnished with a "shut off" on the inlet holes, which, when closed compelled the air of the mine to enter by the holes near the top of the outer shield, and thus to indicate the condition of the air within about $1\frac{1}{2}$ inch of the roof. As soon as the wick flame indicated the presence of gas, the "shut off" was opened to admit purer air, and to avoid the risk of an excessive quantity of gas extinguishing it. The Hepplewhite-Gray Davy lamp was an adaptation of the Gray inlet tubes to the shielded Davy lamp, the shield having a conical outlet similar to that of the Ashworth-Mueseler B, and was fitted with Ashworth's patent for making practical examinations for firedamp. In the Hepple-

Mr. Ashworth. white-Gray of the Clanny type the inlet tubes were protected from dirt falling down by a horizontal ring, which screwed on the body of the lamp, and formed a "shut off" of the most absolute kind. The shield was fitted with a conical outlet to prevent down currents, and to act also as a Mueseler chimney, and was protected from dirt and the direct action of the ventilating currents of the mine by the perforated top on which the "shut off" screwed. The slightly conical gauze inside the shield was not exposed to any dusty current, and as its only duty was to form another protection to the outlet, its dimensions were very small. Its base was furnished with spun copper rings which clipped the top of the truncated conical glass. This form of glass was extremely strong: first, to resist particles of coal or dirt which might be thrown against it, through presenting two inclined planes to ease the direct action of the blow; and secondly, in its adaptability to resist sudden expansion or contraction, because the increase of the diameter of the small end by heat was less than that of the large end, therefore the increase in length was compensated for by the increase in the larger diameter without perceptibly increasing the perpendicular height of the glass. A screwed ring secured this glass in the ordinary way, and was followed by a ring with rectangular openings covered by a strip of gauze, which ring, when screwed close up, left an annular space at the foot of the inlet tubes, and allowed the entering air free ingress to the wick-flame through the strip of gauze. One or more of the inlet tubes of the Hepplewhite-Gray lamps were furnished with Ashworth's arrangement for making practical tests for firedamp, consisting of a hole near the base of the tube, and covered by a slide. It had been discovered, that theoretically the Gray arrangement was the best for obtaining accurate indications of the state of the mine close up to the roof; but practically it was wrong, as when gas entered the tubes it was compelled to pass through the lamp before any fresh air could enter. Thus, in most instances, the wick flame was extinguished, and the lamp rendered useless for making further examinations until relit. When testing with the new arrangement, the slide was pushed up, and the hole in the tube left wide open, thus gas could enter by three tubes from the extreme top, and fresh air from the base of the other; and, supposing that gas did thus enter, it was consumed on one side of the flame whilst the flame itself was maintained by the current of fresh air on the other side. If, on reaching the highest point of the mine, in this way no gas was found, the official gradually closed the hole with his thumb, or with the shutter, and

if no trace of firedamp was then found, it was certain that the place was absolutely clear. He made all tests for gas with the wick flame at its normal height. Thinner strata and smaller percentages of firedamp could be detected with the Hepplewhite-Gray fireman's lamp than with any other shielded lamp.

Mr. J. B. ATKINSON observed that the Author had devoted much attention to mine-accidents, and his high scientific attainments had been of great service to the mining community. But he thought the Author had not yet realized the full importance of the influence of coal-dust in colliery explosions. In stating this it might be remarked that, with no precautions against the existence of firedamp in the passages of a mine, disastrous firedamp-and-air explosions would be frequent; but considering that all the endeavours of mining engineers in the past had been devoted to the prevention of such occurrences, and that these efforts had produced a direct effect in promoting accumulations of coal-dust over long distances, and that in dry mines coal-dust in dangerous quantities was much more ubiquitous and continuous than firedamp, it was a matter of no surprise that the part played by coal-dust in mine-explosions was much more disastrous than the part played by firedamp. Several considerations in favour of the belief that coal-dust was often the main agent of destruction in mine-explosions, and of the view that explosions might originate from, and be propagated by, coal-dust under certain conditions, in air free from any firedamp other than a trace, were advanced in the book "Explosions in Coal-Mines," referred to by the Author. As some of the facts and opinions advanced therein were new, and had not been noticed by the Author, he would venture to refer those interested in the question to the book itself. On the 13th of March, 1884, a disastrous explosion occurred in the Pocahontas coal-mine, Virginia, U.S.A., involving the loss of one hundred and fourteen lives. From a report published in the "Transactions of the American Institute of Mining Engineers,"¹ it appeared that firedamp was unknown in the mine, which, however, was very dry and dusty. The report gave as a condition leading to the explosion "the probable existence of small quantities of firedamp slowly given off from the coal;" but it also stated that "the existence of firedamp in the Pocahontas mine is the disputed point," and nothing was advanced to prove its presence. The Author's statement that explosions ascribed by some to coal-dust and air alone was

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¹ Vol. xiii. (1885) p. 237.

Mr. J. B. open to the criticism, that "experimental results which serve to support" such opinion, "are more or less exceptional in character, or that they have been attained under conditions which do not approximate to those likely to occur in a mine," might be opposed by the following considerations. In the many miles of roads in dry mines where coal was led by engine-power against rapid currents of air, causing the formation of deposits of coal-dust of the finest and most inflammable character, in positions where the explosion of a shot must dislodge quantities of it, and where the speed of the air sustained it as a cloud, occasionally, conditions even more favourable than any yet provided in experimental researches, for the ignition of the dust, in air free from firedamp, might be attained. When it was found that shots fired in such roads were the rarest class of shots fired in a mine, and when it was further found that the firing of such shots was often accompanied by an explosion, was it unreasonable to conclude that what had been observed in experiment had occurred in practice; and, while not maintaining the absolute freedom from firedamp of the air (although many mine-managers would maintain it), yet to admit that, so far as evidence could be obtained, the air did not contain sufficient to have any influence on the result? Instead of its being an assumption, as the Author considered it, to maintain that the air in an intake air-way was so free from firedamp as to be perfectly safe, so far as it was concerned, whether coal-dust was present or not, the assumption was in supposing firedamp in definite volume to be present in the absence of any evidence. The fact that 2 per cent. of firedamp must be present, before it could be observed by the safety-lamp, afforded no presumption that a definite volume under 2 per cent. was present in an intake air-way where an explosion had occurred. As the lamp in such situations afforded no test, other considerations must be the guide, and it might be stated that the probable amount of firedamp normally present in intakes was more susceptible of estimation than that present in other parts of the mines. He differed from the Author in the opinion that, in the passages of a mine, the combustion of coal-dust in air was gradual, and attended with less violence than the combustion of firedamp and air, or of a mixture of firedamp, coal-dust, and air; his experience pointed to the reverse being true, with the following exceptions, which he thought might go far to reconcile divergencies of opinion:—(1.) Where the coal-dust was coarse and confined to the floor, as in working-places at the face and roads adjoining, the violence developed was small, even if, as must often be the,

case in such situations, a definite but small amount of fire-damp was present in the air. (2.) Where coal-dust in a fine dry state existed more or less on all the surfaces of a haulage road, from 50 to 80 yards from the point of origin of an explosion of coal-dust, with air free from firedamp other than a trace, no great violence was observable, and probably the passage of the flame had been gradual. (3.) If over a long distance in a confined passage in a coal-mine, a thoroughly diffused mixture in the most explosive proportion of firedamp and air existed, then probably great violence would be produced on its ignition. It was difficult to point to any great explosion where even the probability of the last condition could be asserted. In the return air-ways of a coal-mine, it might be expected with far greater probability than in the intake air-ways, but great explosions did not affect to any considerable extent the former class of roads. The speed of flame, or rapidity of combustion of a homogeneous gas-and-air mixture, probably reached its maximum within a short distance of the point of ignition, while the reverse was probable in the case of a coal-dust-and-air mixture; if this was true, no experiments had yet been made on a scale of sufficient magnitude to test fully the phenomena of explosions of coal-dust and air. As to the nature of the combustion of coal-dust in air free from firedamp, he would venture with great diffidence to make a few remarks. As a factor, possibly contributing to violence, it might be mentioned that, contrasting a firedamp with a dust-explosion, in the case of the former, if of the most explosive mixture, one-tenth of the amount of oxygen would be replaced by firedamp; while with the dust the road was filled with air, the amount of oxygen limiting the amount of combustion; there was in this way an advantage for the dust. The possibility of a further supply of oxygen existing in the fine dust on the upper parts of a haulage road was worth attention. The combustion in the case of coal-dust might be either that of the gas expelled from the dust, or, if the particles were very minute, possibly the solid matter might be consumed; but in either case, the finer the dust, the more rapid would be the combustion. Supposing the combustion to be that of gas expelled from the dust, then the Author's discovery of the power of finely-divided, even non-inflammable bodies, of promoting inflammation would further help to increase the rapidity of combustion.

Mr. W. N. ATKINSON remarked that various theories had been promulgated in order to account for the occurrence of explosions in coal-mines. Amongst them were blowers or sudden outbursts

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Mr. W. N. of gas, the accumulation of firedamp in goaves, or abandoned workings; the influence of atmospheric disturbances; movements of the earth's crust, or earth tremors; and the presence of coal-dust. It might be pointed out that the only one of these possible causes known to have been present in all extensive explosions, of which there were sufficient records to enable a judgment to be formed, was coal-dust. Sudden outbursts of gas were known to occur sometimes; but many explosions had been attributed to them when no evidence existed that such an outburst had taken place, and where, even if the outburst had occurred, it would be impossible to account for the result by it alone. Extensive explosions had happened in pits where there was no goaf, and in some cases where there were no abandoned workings. The most careful study revealed no sustained connection between large explosions and meteorological conditions, although it was well known that the movement of firedamp in goaves and open spaces was governed to an appreciable extent by atmospheric pressure. The usual opinion was that the period of greatest danger from firedamp was when the barometer was low, and that was probably correct, when modified by the knowledge that the gas was more sensitive to changes of pressure than the mercury. The "colliery warnings," now periodically given in the public press, appeared to indicate that the periods of high atmospheric pressure were considered the most dangerous, but on what grounds was not apparent. The possible influence of earth tremors on explosions had not been sufficiently studied to allow of any positive conclusion on the subject; it was as yet an entirely speculative question. With regard to the influence of coal-dust, it might be pointed out that no extensive explosion had taken place, in recent times, under circumstances which precluded the possibility that coal-dust might have been the chief agent in operation; and the same held good so far as could be judged from the records of explosions in former times. The conclusions arrived at as to the cause of colliery explosions, when the influence of coal-dust was not taken into consideration, were vitiated for that reason. It was a recorded fact that in many recent cases the explosions were confined to those passages in the mines which contained much coal-dust, and did not traverse any roads which were free from coal-dust; even although the roads containing the coal-dust were the intake air-ways, and the roads free from it and not traversed by the explosions were the return air-ways. Indeed, cases were known where the explosion was actually confined to the dusty main intakes, and did not penetrate to the working faces, or affect the return air-

ways. This was so at the Seaham Colliery explosions in 1871 and 1880; at Tudhoe Colliery explosion in 1882; at Mardy Colliery explosion in 1885, and at the Altofts Colliery explosion in 1886. In all the above cases, except Mardy, shots appeared to have been fired in the main intakes coincidentally with the explosions. At Mardy the explosion was probably initiated by the ignition, by a naked light, of an accumulation of firedamp in a cavity in the roof where the stone had fallen, to the height of nearly 30 feet. It would probably not be difficult to prove by means of Liveing's indicator, or the Pieler lamp, that the large volumes of air passing along the main intake air-ways of such collieries did not contain even the very minute quantities of firedamp which these instruments were capable of detecting. The recently passed Act for the regulation of mines did not provide for the systematic damping of coal-dust in dry mines, so that, so far as the law was concerned, they might remain in the same state in that respect as they were before. The Act, however, provided that precautions should be taken to prevent the ignition of coal-dust either by gas or by explosive substances. For the purposes of the watering required by the Act, which was limited to the locality where shots were about to be fired, it was desirable that some efficient means should be introduced for distributing the water effectually. The Anchor engine referred to by the Author appeared to have this object in view, and a more detailed account of it would be interesting. Another method might be by the application of a small pump, or fire-engine, worked by hand and fitted to an ordinary water-tub; the water being forced through a flexible tube, and delivered in the form of spray. What was required was a means of applying the water with facility and precision to any part of a drift, whether roof, bottom, or sides. Efforts were now being made at several collieries to damp the dust in a systematic manner; but sufficient experience had not yet been obtained to indicate the most efficient way, which would probably vary according to the conditions existing at different collieries. In some cases small pipes containing water under high pressure were laid along the dusty haulage roads, with cocks at suitable distances apart, to which a hose-pipe was fixed. In this way every part of the passage could be literally washed. In other cases short branch pipes were taken from the main range into the centre of the drift, and the water was allowed to escape, against the air-current, in the form of fine spray, through a minute aperture. The distance to which the spray thrown out in this way would effectually damp all parts of the passage did not appear to be great, and

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Mr. W. N. Atkinson. if too much spray was thrown out at one place the bottom got too wet there. This might be obviated by having sprays at more frequent intervals, and only allowing every second or third one to be in operation at the same time. This system had the advantage of being self-acting, and requiring little attention. Efforts had also been made to cause the ventilating current itself to damp the dust, by raising its temperature and saturating it with moisture when it entered the mine. Methods for mechanically distributing water carried in tubs had been devised by Messrs. Archer and Robson, and by Mr. J. A. Ramsay. The proper use of the water-cartridge with high explosives in blasting greatly reduced the risk of igniting gas, or coal-dust, but at an increased cost. In the North of England it had not been found suitable for getting coal. The compressed lime-cartridges had been tried at several collieries in Durham, but their use had been discontinued. Under favourable conditions (which were, perhaps, not very general) the method seemed to be a good and safe one for getting coal. It was of little use for stone-work. It might be mentioned that on more than one occasion, where the paper in which the cartridges were wrapped was put into the cartridge-hole as stemming, the paper was ignited by the heat evolved from the lime, and was found smouldering when the coal fell. It was unnecessary to put paper, or other inflammable material into the holes. In one case a man was severely injured by a blown-out lime-cartridge shot. Trials were about to be made in Durham of some of the recently invented explosive substances said to produce no flame, or at any rate, to be incapable of firing gas or coal-dust. If such a substance could be found with explosive properties similar to gunpowder, and capable of being used in shot-holes of the same size as was necessary for gunpowder, it would be hailed with delight; for none of the new methods of coal-getting approached the use of gunpowder for general applicability, convenience, and economy.

Mr. Brough. Mr. BENNETT H. BROUGH remarked that the results of the investigations described by the Author deserved careful attention, not only from coal-miners but also from metal-miners. For, unfortunately, firedamp was not confined to collieries. In a number of cases it had been met with in mines of lignite, of salt, and of metals. Indeed, the first fatal firedamp explosion recorded took place, in 1664, not in a colliery but in a salt-mine at Hallstadt in Austria. An illustration of the diastrous effects of a firedamp explosion in a metalliferous mine had been afforded by the lamentable accident at the Mill Close lead-mine, in Derbyshire, on the 3rd of November last,

when five men lost their lives, and others were injured, by the ignition of firedamp, caused by firing a dynamite charge. The deposit of lead ore at that mine occurred in dark limestone beds immediately below the Yoredale shale that separated the limestone from the Millstone Grit. This shale, whenever it occurred in beds of 25 to 35 fathoms in thickness, always gave off a little gas. Probably this gas had collected in the fissured limestone, and becoming ignited by a shot, forced down the rock masses upon the unfortunate miners. The mouth of the great adit level which drained many of the Derbyshire mines, known as the Hill Carr Sough, was in the vicinity of the Mill Close Mine. This adit or sough passed through the shale for 2 or 3 miles, and with a candle at the end of a stick, up to a very recent date, visitors used to light the thin stream of gas along the roof. This would flash along almost the whole length of the level. The gas was now exhausted, or was found in very small quantities, but, when new ground was cut, there was a decided emission of gas. Similarly, outbursts of firedamp had been observed at the Van lead mine, near Llanidloes, at the Silver Islet mine in Lake Superior, at Monte Catini in Tuscany, and at several of the Saxon metalliferous mines. Inaccurate mine-surveying was a frequent source of accident, which was dwelt on neither in the report of the Royal Commission, nor by the Author. A glance through the reports of H.M. Inspectors for a number of years would show that several of the accidents therein recorded were obviously due to a neglect of the variation of the magnetic meridian, to which mine plans were usually drawn. Thus, Mr. T. Evans recorded an accident in 1875 at a small colliery in Nottinghamshire, where the men holed into some old workings. The disaster was caused by the men working according to plans one hundred years old, which showed a barrier of 100 yards. Another accident from holing into old workings was recorded, in 1878, by Mr. J. Dickinson. The men were working, without any bore-holes in advance, and thus an inundation was caused whereby two lives were lost. In that instance there was a correct plan of the former work, but, by a mistake in the surveyor's office, a wrong direction had been set out. Now that the means of constructing accurate mine plans were more abundantly taught, such accidents would, it was to be hoped, be of rare occurrence.

Mr. T. FORSTER BROWN observed that the thanks of the community were due to the members of the Royal Commission for the practical turn which they had given to the direction in which increased safety in working coal-mines could be secured. With regard to explosions of firedamp; thoroughly efficient damping

Mr. Brown. of the coal-dust would add immensely in reducing this risk. At large collieries with which he was associated, extensive lines of water-pipes had been laid along the main haulage roads, with a water-pressure of 100 lbs. per square inch, and with outlets giving off fine spray at intervals of about 40 yards apart, with most beneficial results. Not only had the dust been damped, but the temperature had been reduced. At Harris's Navigation Colliery the temperature had by this means been reduced 6°. Mr. Henry Martin, of Dowlais, had introduced a considerable improvement by combining water under pressure in pipes with compressed air, which enabled the moisture to be more finely disseminated throughout the passages of the mine. Upon the question of shot-firing, at the suggestion of Mr. Galloway, two or three years ago, blasting-gelatine tamped with wet moss had been adopted as an explosive with good results, and so far no flame had been observed to pass. The next great desideratum no doubt was a safe lamp, giving an effective light. Several of the improved lamps of the present day would resist a strong current; but apart from the question of danger from explosion, a considerable reduction ought to be expected in the loss of life due to falls from the roof and sides, if a thoroughly good light could be introduced into fiery collieries. This difficulty, however, seemed to be approaching a solution by means of the electric lamp. Mr. Swan had devised an excellent electric lamp, which in turn would be improved upon, and Mr. Forster Brown anticipated the speedy invention of a thoroughly efficient self-contained electric lamp. With such a lamp it would be practicable to light the main hauling roads with fixed lamps, and to reduce the number of riders upon the sets, and in that way diminish the risks upon the haulage roads. He had adopted in many cases in the main haulage roads, where compressed air was available, a system of engines at each end of the main planes, doing away in that way with the tail ropes, and simplifying the operation of hauling. With well-lighted haulage roads of sufficient width, and laid with heavy rails, the risks of injury and loss of life ought to be reduced to a minimum. The system of long-wall working, as practised in South Wales, as compared with any other mode of working was attended with the least risks; and having regard to the fact that, up to within 150 yards or 200 yards of the face of the workings, the ground settled on the goaf up to the surface, he did not go quite so far as to consider the goaves a source of accumulation of gas. It must be so, more or less, with regard to the width of goaf, which had not settled down; but when the face advanced to the rise, the gas flowed out to the face, and in the

case of the workings going to the dip, the tendency would be to accumulate in the goaf. With regard to shaft-accidents, the difficulty was to avoid increased complications. Taking the case of the Harris Navigation Colliery, where the load was 19 tons, running at the rate of about 30 miles an hour, in the middle of the pit, the guides being iron rails. Less weight would not suffice to obtain a reasonable output from such a great depth, and any apparatus in the shaft for counteracting a breakage of the rope would be extremely difficult to invent, and the cure would probably be worse than the disease. The course to adopt was, in his opinion, to have every part of the machinery of ample power, the engine well balanced, an automatic steam-brake attached, an efficient system of signalling from top to bottom and bottom to top, and detaching hooks below the pulleys.

Mr. S. B. COXON, during the spring of the year 1887, by permission of the Imperial German authorities representing the Department of Mines, had the good fortune to witness a series of experiments on the properties of so-called high explosives; these were conducted by the mine-inspector of the district at the Government experimental works adjoining the König mine, Neunkirchen. As these works had been erected to enable the Firedamp Commission to carry out tests on a scale approximating to the conditions met with in coal-mines, the Government had spared no expense in rendering them complete in every detail. The works consisted of a tunnel 51 metres long by 1·70 by 1·20 metre, strongly built to resist the force of explosions, and strengthened by iron girders, hoops, and stays. The top of the tunnel was provided with large safety plugs and doors, which yielded to the effects of explosion, and formed, so to speak, so many safety-valves. At frequent intervals small squares of strong glass were let into the sides of the tunnel, to enable the observers to watch in safety the behaviour of shots in the various mixtures of firedamp and coal-dust in which they were tested. The firedamp was piped from a blower in the mine, and was received by a suitably constructed gas-holder, from which it was easily admitted into the explosion-chamber in such quantities as the experimenter might require; but, as a rule, the testing mixture consisted of 10 per cent. of mine-gas CH_4 , and about 15 kilograms of finely pulverized coal-dust scattered over the drift, a large proportion being held in suspension by the air in the chamber. The shots were fired by electricity. The staff was well supplied with instruments, and possessed all that was necessary to carry out their experiments with scientific accuracy. The Government Inspector,

Mr. Coxon. Mr. Fabian, illustrated the effects of blown-out shots in an atmosphere containing coal-dust in a fine state of division without any mixture of firedamp. The charge consisted of 230 grams of ordinary black blasting-powder. When the shot was fired a tremendous explosion took place; all the safety plugs and doors were blown out, and flames, accompanied by clouds of smoke, burst through every opening. After the explosion a layer of fine coke-dust was found deposited on the floor and sides of the tunnel. This experiment was twice repeated with like results; the explosions appeared to be almost as violent as when mine-gas formed part of the mixture. It might be well to mention that the coal-dust was from the Pluto mine; it was friable, bright and bituminous, in appearance not unlike the duff from the gas coals of the Durham coal-field. There could be no doubt that in these experiments the explosions were instantaneous, and no mere elongation or extension of flame. He thought it might not be without interest to place on record his experience of an explosion at a colliery under his management some twenty-five years ago, which appeared altogether due to a blown-out shot firing the dust in suspension in the mine. The circumstances, briefly stated, were as followed:—A drift was being driven between the down and upcast shafts for the purpose of erecting an additional ventilating furnace. The coal being friable, a quantity of dust became mixed with the ventilating current. After the drift had been carefully examined for gas, not only by a Davy lamp, but also with a naked light, a shot was fired, but having been unskilfully placed, it was blown out; the result was an explosion which burned severely a number of men who were working near the downcast shaft. The air-current, in volume over 150,000 cubic feet per minute, was checked, the separation doors were blown open, and the effect of the blast was felt at the bank. In this particular case not the slightest indication of gas was apparent, nor was any observed either before or after the explosion. No fall had taken place, nor had anything occurred to interrupt or derange the ventilating current. After a careful investigation of all the circumstances, the conclusion arrived at was that the accident was caused by the blown-out shot igniting the coal-dust. Granting that the examples given were faithfully represented, the lesson was of easy application, and would show that there was a strong probability that coal-dust had played an important part in many accidents, the proximate causes of which had been enveloped in mystery. It was to be feared that so long as ordinary blasting-powder was used in coal mines, blown-out

shots would be an ever-recurring source of danger. It would, Mr. Coxon, however, appear that the time had arrived to take a new departure by substituting other blasting compounds. A cartridge had recently been invented that was quite flameless, and which had undergone the most severe tests in mixtures of firedamp and coal-dust. Perhaps the most noteworthy test to which this cartridge had been subjected was in 10 per cent. of mine-gas and finely pulverized coal-dust. A number of experiments were made in this highly explosive mixture, and in no case was it fired. Not less remarkable was the fact that when this cartridge enclosed dynamite or blasting gelatine, these powerful compounds ceased to emit flame without any apparent loss of strength. Photographs had been taken at the instant of firing, which might be cited as truthful and scientific testimony to the value of this discovery. It was not surprising that mining engineers, having the management of extensive and dangerous collieries, had long been seriously impressed with the risks daily incurred by treating the ordinary Davy as a safety-lamp. It was well known that these lamps, when exposed to inflammable mixtures, would pass flame in currents of a comparatively low velocity. A large colliery required a ventilation of from 200,000 to 300,000 cubic feet of air per minute, consequently many of the splits must of necessity attain high velocities. It was difficult to imagine a greater source of danger than when a loaded current at a high speed impinged on the unprotected gauze of the Davy type of lamp. Many of these lamps would fire an inflammable current if the velocity reached 8 or 10 feet per second. It was not necessary here to emphasize the danger from such a condition of things. Another fruitful source of danger arose from falls in goaves, which in deep mines generally contained accumulations of firedamp. When fractures occurred in the superior strata, and the roof fell, the contents of the fissures were driven into the working-places, and not infrequently filled the lamps of the workmen with inflammable gas; this contingency should be guarded against with the greatest care; indeed, there were many reasons why the attention of mining engineers should be directed to other sources of light and safety. Happily electric lamps pointed to a solution of the difficulty, and in what direction the end in view might be most easily attained. There could be little doubt that in the electric lamp there was the nearest approach to absolute safety, whilst the superior light would add much to the comfort of the collier, and tend in no slight degree to ameliorate the disagreeable nature of his vocation. A judicious selection of the kind of battery to

Mr. Coxon. be used was of the first importance, as, given the proper battery, the form and arrangement of the lamp were matters of detail. It might be of interest to show how closely electricity approached oil in point of economy. The result of several weeks' consecutive testing showed that the Schanschieff lamp (primary battery), yielding a light of 2-candle-power, cost only $\frac{1}{4}$ d. per shift of eight hours. This was a single fluid battery of high electromotive force and low resistance. The cells consisted of zinc and carbon, the solution being a basic sulphate of mercury. The action was remarkably constant; there was no danger from sparking; the lamp gave off no gas nor fumes of a disagreeable odour; there was nothing in either the construction of the lamp or the nature of the solution to produce a risk of explosion. The weight of a four-cell lamp was 4 lbs. 6 oz., and the three-cell was only $3\frac{1}{2}$ lbs. These lamps might be changed as easily and in a shorter time than it took to trim a Davy lamp.

Dr. Foster. Dr. C. LE NEVE FOSTER, in reference to deaths from accidents and disease in metal-mines, said he had pointed out on more than one occasion, in his official reports, and in papers read before the British Association and the Statistical Society,¹ that the ore-miner had very nearly as dangerous an occupation as the collier, and that in some metalliferous districts, such as Cornwall, the average death-rate from accidents was higher than in coal-mines. In other words, as has been frequently shown, though the fact was scarcely rooted in the public mind, firedamp was not the miners' worst enemy. Nay, he would go further, and almost look upon it as a blessing in disguise. If it had not been for explosions in mines, there would have been less stringent regulations for their safety. The numerous dangers, which caused only one or two deaths at a time, would have been less carefully guarded against by statute, and ventilation would not have received that strict attention which was now an absolute necessity. Though not killed by explosions, the colliers would have had their lives shortened, by breathing vitiated air, like their brethren in Cornwall. In considering the well-being of a class of workmen, such as miners, it was necessary to look at the mortality from disease as well as the mortality from accidents. It had been shown by Dr. Ogle² that, in spite of accidents, the death-rate of coal-miners was not high. In order of comparative mortality, coal-mining

¹ Journal of the Statistical Society, vol. xlviii. p. 277.

² Supplement to the 45th Annual Report of the Registrar-General of Births, Deaths and Marriages in England. London, 1885, pp. xxvi. and xlix.

stood 30th in the list of ninety-four occupations which he cited, Mr. Foster. whilst mining in Cornwall was as low as No. 91; that was to say, only three of the ninety-four trades exceeded tin-mining in deadliness. His late colleague, Mr. Frecheville, called attention to this fact in his report for 1885, and ascribed this high mortality to inadequate ventilation, and excessive climbing of ladders from deep mines. He quite agreed with Mr. Frecheville in this opinion, and he had stated in his official reports that these evils, together with others, demanded an amendment of the statute of 1872, which regulated the working of metalliferous mines.

Mr. W. GALLOWAY stated, in reference to the Author's remarks Mr. Galloway. on the quantity of air necessary to the combustion of 1 lb. of coal-dust,¹ that in January 1876, a month after the completion of his first experiments, with definite proportions of firedamp and air, and with undetermined quantities of coal-dust, he wrote in a Paper, published in the Proceedings of the Royal Society in the following March, that "It is always possible, however, that if coal-dust could be made fine enough, and were thoroughly mixed with dry air in the proportion of about 1 lb. to 160 cubic feet of air, the mixture might be inflammable at ordinary temperature,"² and so on. He arrived at 160 cubic feet of air by taking 12 lbs., the weight of air necessary for the complete combustion of the fuel given at p. 280 of Rankine's "Steam Engine," 1861 edition, and calculating its volume at ordinary pressure and temperature. It had appeared to him that if complete combustion of the elements of the coal-dust could be assured, without any surplus of oxygen, the best possible results would be obtained, and that might be explosion in a confined space. In a subsequent Paper published in March, 1879, he stated that "The proportion of coal-dust which gave the best results, was much larger than might at first sight be thought necessary, namely, about 1 oz. of dust to a cubic foot of air for all mixtures of gas and air, ranging between one of gas and twenty of air, and one of gas and forty of air. Also, in one of the experiments, with the return air of a mine, which I propose to describe in this place, the air requires to be literally black with dust before it will ignite."³ The last mentioned results were afterwards corroborated by Messrs. Mallard and Le Chatelier.

Mr. MAX GEORGI, of Zaukerode, thought that hardly sufficient im- Mr. Georgi. portance had been attached by the Author to the subject of auxiliary ventilation. On the Continent, with the pillar-and-stall method of

¹ *Ante*, p. 43.

² Proceedings of the Royal Society of London, vol. xxiv. p. 369.

³ *Ibid.* vol. xxviii. p. 411.

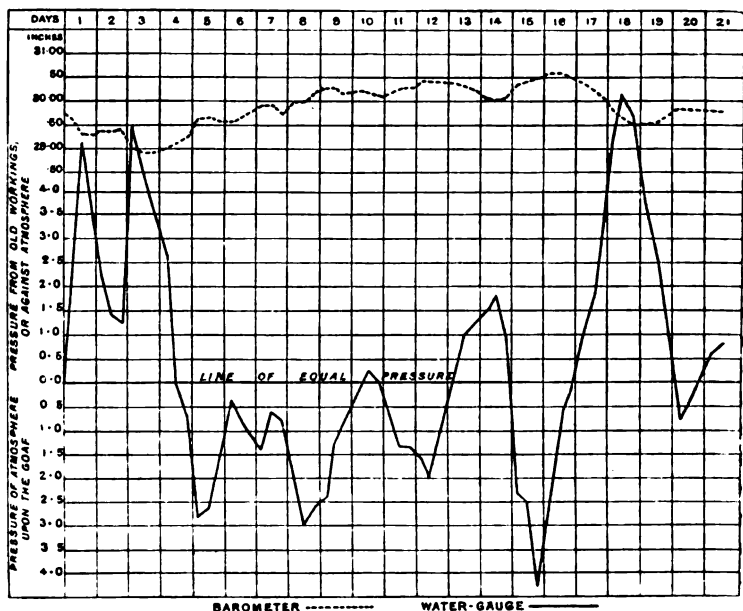
Mr. Georgi. working coal generally employed, auxiliary ventilation was of very great importance. In driving narrow bords, and occasionally, in consequence of dislocations of the seam, or of great pressure of superincumbent strata, it was difficult or impossible to pass a ventilating current of air through the workings. In these cases the ventilation could be obtained only by diffusion. Still, this method would be a dangerous one; for with a violent outburst of mine-gas, diffusion would, under certain conditions, be insufficient to prevent the formation of explosive gas-mixtures, or of an air-mixture liable to cause a coal-dust explosion. It should be added that even the narrow dimensions of the bords driven in the unbroken ground might cause the gas at the firing of a shot to acquire greater velocity, and the coal-dust produced by the shot, or lying in the drift, to be whirled with greater violence to and fro. If this agitation of the coal-dust could not be prevented as long as blasting was permitted, all measures for avoiding accidents must aim at drawing the coal-gas away from each working place, or of mixing with it sufficient fresh air to prevent the proportion of gas exceeding a dangerous percentage. The colliery rules, promulgated by the Saxon Government on the 25th of March, 1886, insisted, paragraph 113, that those points, where men were at work, and where the ventilation was accomplished by a current of air, must be kept free from fire-damp by auxiliary ventilation. This might be effected either by the main ventilating current, or by an auxiliary air-current produced for the purpose. In the former case, if brattices were not to be employed, the main air-current must be further subdivided, splits being formed by means of pipes. The more the main current was interrupted and limited in this way, the more would its total effect be diminished, thus detrimentally affecting the whole of the ventilation in favour of certain working places. When, on the other hand, recourse was had to auxiliary ventilation for several working places, the application of the main ventilating current should be entirely avoided, or be limited to certain cases. The most simple, the most convenient, and the most successful method was the employment of compressed air, whether blown direct, or by a Körting blower or similar jet, into the ventilating pipes. Inasmuch as compressed air not only transmitted power, but also had a ventilating action, it far excelled steam or water-power for working blowers of the injector type. When available, either of the latter might be used more advantageously for driving a ventilator, turbines acting directly on the axle of the ventilator being especially suitable for the purpose. Dynamos were

also extremely valuable for this purpose, especially where the source of power was at a greater distance from the place where the power was utilized. As a rule, all these machines were so arranged that, by blowing, they brought to the working place air free from gas. Recently, contrivances had been suggested for exhausting the gas, each working place being connected with a branch pipe, to suck the air from the highest point where the gases usually collected. The gas thus obtained would be conducted separately to the surface, where it might be advantageously used for heating boilers. Although this method was excellent in principle, it remained to be seen whether good results would be obtained in practice; since there must be a difficulty in keeping a long length of pipes airtight, and at the same time regulating the exhausting action. Auxiliary ventilation was also of importance for mines containing carbonic acid gas. Although the immediate danger of accident was slight, as the presence of this heavy gas was generally indicated sufficiently early, by the extinguishing of the miner's light; still there was no doubt that a slow but constant poisoning by carbonic acid gas was the cause of premature marasmus, and that the irritation of the respiratory organs by carbonic acid gas was the cause of the diseases of those organs, from which so many miners had suffered. This was a danger to which, perhaps, as many miners had fallen victims as to firedamp, and to combat it no method seemed more efficacious than auxiliary ventilation combined with good total ventilation. Although the employment of the water-cartridge was a security against the danger of firedamp in collieries, it was, however, necessary to bore holes deeper than would otherwise be wanted, so that there was a great practical drawback to their use. This disadvantage was obviated by an invention by Messrs. Müller and Aufschläger, who incorporated with the explosive itself the water necessary for extinguishing the flames of the shot. He alluded to the so-called firedamp dynamite (*Wetterdynamit*). This invention consisted in mixing salts having a high proportion of water of crystallization with the dynamite; for example, about 40 per cent. of soda with ordinary dynamite, or of alum with gelatine-dynamite. Soda gave with gelatine a substance as hard as stone, and was consequently unfit to be used with gelatine-dynamite. This proportion of loosely combined water acted in a manner quite different to hygroscopic water, which completely destroyed the blasting power of gunpowder as well as of dynamite. The safe nature of the flame of the firedamp dynamite, especially of soda-dynamite, had been proved by experiments made by the Prussian

Mr. Georgi. Government authorities. It was now only necessary to consider its practical value in coal-getting, and of this trials were in progress.

Mr. Gresley. Mr. W. S. GRESLEY said, with reference to the instruments employed for indicating the effect of atmospheric pressure upon the gas pent up in the goaves of coal-mines, that he had found nothing superior to the ordinary U-shaped water-gauge, used, as he understood, for the last five or six years in the Seaham Colliery, Durham, as employed for ascertaining the friction or "drag"

FIG. 1.



Depth of pit, 690 feet; instruments about 570 feet below sea-level; observations taken every eight hours.

on ventilation. He had used this instrument for the last few years in a colliery in which the whole of the present workings were in main-road pillars, on either side of which were extensive areas of "wastes," or old workings, containing firedamp. These old places were sealed up by stoppings constructed of clay. The water-gauge had one leg connected to a pipe which passed through one of these clay dams into the old goaves, the other leg being open to the atmosphere. The practical use of this gauge was that its fluctuations, being eight to ten times as

great as those of the mercurial barometer, showed more clearly Mr. Gresley.
 what the atmospheric pressure was at the time of observation.
 The water-column appeared to move as much as from six to twelve
 hours sooner than the mercury, thus enabling those in charge of
 the workings to know what to expect, and to exercise special
 care in cases where coming stormy weather was indicated. Fig. 1
 (reduced from actual readings) was sufficient to show the great
 value of some such weather-indicator as this. He placed confidence
 in the water-gauge readings, far before those of the ordinary
 barometer, as a "Colliery-warning" Indicator.

Mr. Longden.
 Mr. J. A. LONGDEN remarked that, at the Blackwell collieries, there
 were three hundred doors to regulate the air in the mine. Boys
 were not employed as trappers; and evidently it would be impos-
 sible to obtain three hundred boys to do this work. During the
 nineteen years he had been practically managing collieries he had
 only had one boy killed, and that was through the horse starting
 whilst the boy was coupling the wagons together. He thought that,
 if the causes of boys' deaths were arranged under different heads, it
 would be found that many more were killed through accidents whilst
 coupling wagons together than from the cause assigned in the Paper.
 He had used safety-hooks ever since they came out, and had
 reason to be thankful for having done so. Winding-engines at
 collieries now drew a weight of 7 tons and upwards a distance of
 400 or 500 yards in not much more than half a minute. This
 meant that the engine started, attained a velocity in some cases of
 50 miles an hour, and stopped in thirty seconds; and this was
 going on incessantly for nine hours every day. If, through any
 accidental sticking of the valves, the engine became unmanageable,
 as had happened a few times, no automatic brake would be of the
 slightest use, and the velocity at which the immense weight came
 up the shaft would smash the timbers away to which the dis-
 engaging-hook plate was attached, and thus cause a similar acci-
 dent to that at Houghton Main. Safety-clutches had been tried in
 connection with wire guides, but nothing yet had been found of any
 service for high velocities with great weights where wire guides
 were used. It was surprising that hardly ever, if ever, was there
 any collision in the shafts, considering that, if the chairs were put
 opposite one another in the middle of the shaft, they could be made
 to hit each other by simply pulling one of them with one hand.
 The great diminution in the number of deaths through falls of
 roofs and sides, namely, 40 per cent., comparing the ten years
 ending 1880 with the ten years ending 1860, seemed remarkable,
 taking into account the much greater depth at which mines were

Mr. Longden. now worked, and that the working faces were so much further away from the bottom, which of course meant considerably more road to maintain, and much more road for the men to travel through to get to their work and back again every day. He had tried coal-getting by wedges, but found that in a soft seam, when the wedge expanded, it simply lost its effect by squeezing the coal, and did not fetch it down. No doubt wedges would do their work in a hard coal; but the misfortune was, that when the wedges fetched down a block weighing several tons, the coal had to be broken up for loading for removal from the pit. This involved nearly as much labour as if it had not been got down at all. No doubt that, for economy, nothing had yet been produced better than gunpowder. His impression was that many accidents in the past had been the result of using "germans," or straws, instead of safety-fuzes. He had tried these straws, and found that, when the shot took effect, the lighted end flew back in the goaf several yards, so that, in his opinion, they were highly dangerous. Whilst he should rejoice to see a satisfactory testing-apparatus for gas, it must not be forgotten that, in well-ventilated mines, the only gas to be found was in the breaks in the roof, which penetrated sometimes 3 or 4 yards. The method now adopted was for the fire-trier to stand on the top of a tub and thrust his lamp, on the end of his yard-stick, into the fissure as far as he could reach. Any method which did not enable him to reach the same altitude would be practically inefficient. With respect to outbursts, he was glad to notice that the Author spoke highly of the long-wall system. He considered it the safest method of working, so far as outbursts of gas were concerned. Explosions had been far fewer, and attended with far less deadly results, where the long-wall method had been adopted, than with any other system. He had heard of a goaf being 20 acres in extent without any support. The natural effect of this was that either the floor or the roof would give way, and cause a cavity which would be filled with gas, and as soon as the floor or roof finally burst, the gas which had been penned up in the cavity would be given off. He was of opinion that this was how some of the most serious outbursts of gas had originated. With the long-wall system of packing every few yards, and the roof gradually falling behind the face, this was an impossibility. Compressed lime, he was afraid, must be considered a failure. When he tried it, the lime charred the coal for several inches round the hole, and spoilt the character of it, so that the coal had to be cut out as unmarketable. The same objection applied to compressed lime that he had before

indicated in the case of wedges: it brought down a great weight of coal in a block, which had subsequently to be broken up. The difficulty of illuminating mines by electricity, where wires were connected with batteries at the bottom, arose from the falls of the roof and sides, which would be constantly putting the men in darkness. The objection to the self-contained electric lamp was that the miner would still need a safety-lamp with him to examine if there was any gas in the face. He was one of the Committee in connection with the Chesterfield Institute which conducted a series of experiments on coal-dust. One particular dust, from the North of England, was highly explosive without the addition of any gas whatever. On the other hand, none of the dusts from the neighbourhood of Chesterfield were nearly as explosive, and the dust from Blackwell Colliery could not be fired under any circumstances. But what constituted the inflammability in dust? No doubt some coal-seams yielded dust much more liable to explode than others. There seemed to be an inclination just now to attribute to coal-dust more importance than, in the estimation of many mining engineers, the case deserved. If some Committee could take up the question of the relative risk of explosion, from various dusts under varying conditions, he thought valuable information would be elicited as to the danger of working some seams, and the almost total absence of danger in working other seams of coal. He should like to ask the Author his opinion concerning the origin of firedamp. It had been held by many mining engineers that firedamp could not exist except in the neighbourhood of coal-seams, and that it was not generated by shale or bind. The late explosion in Derbyshire at Wass's lead-mine, which, he supposed, was in the limestone below the Coal Measures, brought forward this question again.

Mr. A. R. SENNETT stated that the safety-lamps chiefly used in Germany were the Mueseler, the S  arbrucker (Boty), the Westphalian, and the Wolf Benzene. The flame of the lamp was in each case enclosed in a glass cylinder, it evidently being considered that the extra risk from breakage was more than compensated for by the extra candle-power obtained. Safety-lamps of any form might be made use of, provided they fulfilled certain requirements drawn up by the Rhenish Mining Board. The control was vested in this Board and five other similar Boards for the various districts, all of whom would shortly issue the conditions they required the lamps to fulfil. Mr. Hasslacker, the Secretary of the Accidents in Mines Board, had informed him that little or nothing had at present been done in lighting mines

Mr. Sennett. by electricity, and that no satisfactory portable electric lamp, either primary or secondary, existed. Neither were firedamp indicators, either as indicators or as recorders, made use of. On this the Board was of opinion that so long as oil lamps were employed the former were scarcely necessary, as it was considered that the lamps themselves acted sufficiently well as indicators. Belgium also was divided into districts controlled by inspecting engineers, the requirements of the lamps being modified according to the nature of the coal. With regard to electric lighting and portable electric lamps in fiery mines, Mr. Sennett felt that it should not be assumed that lamps were absolutely safe, unless provision was made that short-circuiting of the terminals could not take place in the event of the lamp being accidentally broken. The bulb of the glow lamp should, of course, be so enclosed that the miner could not detach it in the mine and thereby produce a spark. Also, there should be no switch nor other gear external to the lamp, or open to the atmosphere of the mine, which the miner could move or tamper with, or which might be accidentally moved. The requisite alteration of the connections for charging and discharging should be performed automatically, so that no skilled attendance should be required in connection with the lamps. Mr. Sennett had constructed a lamp to fulfil these requirements about five years ago, one of which was shown. It was intended to sustain a light equal to about 5 candles for fourteen hours. It was far too heavy and bulky for convenient use, if the accumulators then obtainable had to be used. The contrivances for extinguishing the lamp and arranging the contacts for re-charging the accumulators, for putting the lamp again in circuit and connecting up for discharging, were all contained in an air-tight compartment of the lamp, without any movable connection with its exterior. When the lamp was first put together, compressed air was passed through the plug at the top of the lamp, which was provided with an ordinary oil-skin air-valve, to retain it when the syringe was removed. The effect of the compressed air was to cause the corrugated sides of a small metallic box to collapse, and thereby establish contact through the lamp. The lamp would then continue to burn, but should the glass cylinder become cracked or broken, or the lamp otherwise damaged, the lamp was switched out of circuit, and all connection with the terminals disestablished. When the lamp needed re-charging it would be brought to bank and placed on the charging-table. The action of an electro-magnet beneath the charging-table would cause the lamp to be switched out of circuit,

and the accumulators would be put into connection with two studs Mr. Sennett. at the bottom of the lamp, and which came into contact with the charging terminals of the table. When the lamp was required for use, on its being taken off the table, it immediately became lighted, and all connection with the aforementioned studs was broken. He was not aware if the Commissioners considered it safe to employ electric glow lamps in the ordinary way, in portions of mines likely to contain an explosive mixture. If this were so, it appeared to him that in positions where a fall of roof was likely to occur, the danger of firing the mixture by the spark on breaking contact, when the cables were torn asunder, would be greatly minimized by employing, instead of two separate leads (one — one +), a single cable enclosing both leads encased in an insulating material much more elastic than copper, so that the wires might be broken and the sparking take place before the envelope was broken. This should be in conjunction with automatic gear at the bank, that the circuit might be simultaneously broken there, so that no electrical difference of potential should exist at the fractured ends. And further, the insulation between the leads might be plastic, so that in the event of a large mass of coal or other material falling on the cable, and there being danger of the latter having its leads laid bare, the plastic insulator would yield, and short-circuiting take place within the insulating envelope, and by suitable gear at bank the short-circuiting might cause the cables to be instantly disconnected. Much labour and responsibility was entailed in connection with safety-lamps, on account of the necessity of unlocking, lighting, and re-locking the lamps at bank before they were taken down the shaft. Whilst in Belgium recently he had seen an ingenious lamp, invented by Mr. H. Pieper, of Liège, which obviated this. It was an oil lamp, and similar to other lamps in which a glass cylinder was employed. The wick, however, was furnished with a platinum spiral, to which could be conveniently attached the terminals of an accumulator or primary battery, by means of which the lamp was lighted. It was also provided with an arrangement whereby the light would be extinguished were an attempt made to remove the oil-reservoir, &c., from its glass and gauze case.

Mr. M. H. N. STORY-MASKELYNE, M.P., wished to refer to a matter Mr. Story- which appeared to be vital to the success of any good miners' Maskelyne. lamp in which glow-lights would have to be employed. Only incandescent lamps could be used underground if electricity was to be the means of illumination. A lamp, weighing only 4 lbs. 2 oz., had been exhibited, with which he had a good deal to do in carry-

Mr Story- ing it to its present position of excellence. It had been tried
Maskelyne. under every condition proposed by the mine managers of the
North, and had withstood every ordeal to which it had been
exposed. But for a practical application, on a commercial scale, of
the principle involved in this or any other electric lamp for the
use of miners, it was absolutely essential that their public use
should not be barred by extortionate conditions to be imposed by
any of the patentees of the manufacture of glow-lamps. Mr.
Maskelyne therefore desired to direct attention to the state of the
law in this regard. By the Act of 1883 (Patents, Designs, and
Trade Marks Act), clause 22, this difficulty was entirely met. A
patentee was bound to grant licenses on reasonable terms, and,
failing his doing so, the Board of Trade might order the patentee
to grant licenses on such terms as to the amount of royalties,
security for payment, or otherwise, as the Board, having regard to
the nature of the invention and the circumstances of the case,
might deem just, and any such order might be enforced by
mandamus. It would be an outrageous thing if a patentee, having
the monopoly of the manufacture of glow-lamps, were, by un-
necessary delay in their supply, or by demanding exorbitant terms
for their use, or for the license to manufacture them, to prevent
the great boon of a really safe electric lamp being supplied to the
miners at a reasonable cost. The persons who, with himself, were
sanguine enough to believe that the problem of supplying such a
lamp had been solved, were resolved that the clause in the Act
should be immediately put in force, if this difficulty should be
found to impede their efforts to supply such an economical and
efficient electric safety-lamp.

Mr. Sopwith. Mr. ARTHUR SOPWITH remarked that the Author had alluded to
the utter inadequacy of the light given by certain safety-lamps,
including the Clanny, and this statement could not, he thought,
be materially modified in the case of any of the lately improved
types of lamps, more especially as the bonneting or shielding
of the gauze affected the upward diffusion of light. As the safety
of many lamps, even under extraordinary conditions in an explo-
sive mixture of gas, was practically assured, it followed that any
decided improvement must be looked for in the form of in-
creased illumination rather than in the way of greater im-
munity from explosions. Although there might yet be some
little margin for providing a more efficient light, in the present
types of lamps, it would appear that practically a limit had
been reached in the illuminating power of oil safety-lamps, and
it must be accepted that electric lighting was the only system

from which material benefit could be expected. An experience extending over a considerable time with half-a-dozen Pitkin lamps (which had been in the hands of the colliers and therefore subjected to rough treatment in the working face), was fairly favourable as regarded working efficiency, and at any rate sufficiently so as to afford grounds for believing in the ultimate success of such a system of lighting. Necessarily there was much to be done before the practicability of using portable electric lamps, economically and on an extensive scale, could be determined. It must be considered, however, that while the light of primary or secondary-battery portable lamps was, relatively to ordinary safety-lamps, an adequate one, it was necessarily limited by the requirements of lightness in weight and long-continued action in the cells, and any considerable increase in the illumination of workings must result from the adoption of large accumulator cells, and the use of leads and branch wires. Whether it were desirable or not to aim at an illumination of mines which might more or less approach a luxury, he did not consider that the Author was justified in so arbitrarily dismissing the system of having attached wires to lamps, on the mere ground that they could not be protected. The various details connected with the easy removal, and at the same time protection, of the wires in the workings could hardly have been determined by the trials alluded to, and the matter had, he thought, received insufficient attention. That the system was applicable to working faces must, in the absence of prolonged trials, be taken as a mere opinion, but it was based upon consideration of details in workings where great difficulty was experienced from falling roof and heavy timbering. The statement, made by the Author, as to the obvious liability of the men to get their feet entangled in the leads, presupposed the use of lamps without any order or method; but it must be considered that the necessity of frequent removal of lamps, or alteration in leads, was reduced by the increased amount of light obtainable. Thus 8-candle-power lamps placed 12 yards apart gave a comfortable working light throughout a stall face. In the case of long-wall working (to which alone he had confined his attention in respect to this system of lighting) there seemed little difficulty in protecting the leads and branch wires and lamps; the former could be run along the foot of the cog or pack wall, and the latter against the face of the wall, and so not only completely out of the way of the men, but in a practically secure position. Moreover the routine of lighting presented little trouble. As the working was carried out right and left from the way end, the leads could be gradually extended to the limit of

Mr. Sopwith.

Mr. Sopwith. this stall, say 30 yards on either side. After each "drift," or holing was worked off, no more labour was entailed than the coiling up of the lead and letting out 6 to 7 feet of the main cable, laid along the road from the accumulators, to cover the advance of the face. Apart from the broad question as to whether the introduction of wires should be admissible into fiery mines, there were many difficulties to overcome before the system of lighting with wires attached to lamps could be recommended; but the special difficulty, mentioned by the Author, was in all probability not so insuperable as he implied. Although it was quite probable that the use of leads and branch wires might be proved to be inapplicable as a universal system, the partial lighting by such system might be a useful adjunct in working faces, and it appeared important that the consideration of the protection of, and practical way of economically and efficiently dealing with, cables or branch wires in a mine should not be lost sight of. Apart from the more difficult and intricate question of bringing electric lighting into use at the actual working face, he would direct attention to the facilities that existed in collieries for the economical extension of electric lighting in respect of main cables. This referred to the use of old iron or steel ropes for such purpose. At Cannock Chase Colliery some 4,000 yards of old rope had thus been utilized, and in one instance a cable had been laid having only a resistance of $\frac{1}{2}$ ohm for 1,400 yards, a condition of profuse cable that would not have been thought of if copper cable had been in question. In any extensive system of lighting in bye-roads and stations, the importance of cheap cable was evident. Approximately the relative values of old iron ropes and bare copper cable were, after allowing for difference in conductivity, as 1 to 5, and he could point to conditions where the difference was considerably greater. Some of these ropes had been laid together in a trench on the surface and only insulated with coal-dust and tar, so that little trouble was involved in insulating them in a dry mine. In fact, iron ropes laying side by side on the ground in an underground road, and extending over a distance of 140 yards (single distance) had been found to show no appreciable leakage. The practical experience gained in laying down the cables alluded to, in trenches on the surface, in wet shafts and in roadways underground, and the economy and efficiency of the rough methods adopted in insulating, tended to prove that the problem of extensive lighting underground did not present such great difficulties as might at first be anticipated. He knew of no obstacle, beyond the cost and as yet unproved certainty of any prolonged life of cells, to

very large extensions of electric lighting underground, and he was Mr. Sopwith. by no means sure that the question of lighting the actual face of a working was yet disposed of.

Mr. A. L. STEAVENSON observed that the fact that "miscellaneous" Mr. Steavenson. accidents had not apparently diminished, since 1851, was satisfactorily accounted for, in face of the large quantities of minerals now dealt with, and the high-pressure speed at which all the operations were carried out. He thought not merely the Government regulations, but the increased intelligence and care of the workmen, deserved credit, in that these accidents had not increased. On the other hand, the shortening of the hours of labour resulted in the miner working at a higher rate of speed, which perhaps accounted for the "deaths from falls of roof and sides" constituting a larger proportion of the total deaths in recent years than they did thirty years ago. To provide against these accidents, although forming 76 per cent. of the whole, not much benefit could be expected from the labours of the Royal Commissioners or scientific men; but these labours had afforded great help in all matters relating to explosions of gas or dust, and especially as to explosives and safety-lamps, and to these subjects the Author had naturally devoted the most of his address. It was very instructive, with existing views of the dust theory, to look back at the particulars of explosions in former years, practically never fairly accounted for, say, for instance, the Seaham explosion in October, 1871. Every witness agreed that the explosion occurred at a given point on the main intake. The man who fired the shot survived to say he went about 30 yards out of the way of the shot, and both shot and explosion came together (stone was being blasted at night); he said, "There was no possibility of any gas where we were exploding, as there was sufficient air to drive a windmill;" in fact, 78,000 cubic feet of air per minute were passing this point. The result was that the explosion was assigned to a sudden outburst of gas. Twenty-six persons lost their lives, and in this case, as in almost every one of the explosions in the North of England, dust alone was the only explanation which met all the difficulties which cropped up in the inquiry. Before leaving this particular case he would refer to the Author's allusion to a second or back explosion (p. 22, of the report of Mr. Willis, Inspector of Mines).¹ Witness, a coal-miner, said, "Altogether I heard two explosions after Hutchinson's shot;" the first was a heavy explosion, but the second was not so severe. He had him-

¹ Reports of Inspectors of Mines for year 1871.

Mr. Steavenson. self observed the evidence of a second explosion, when examining the workings after the explosion at Tudhoe Colliery. Baulks of timber, as thick as a man's body, were broken in two, in clearly opposite directions, and although he did not at that time believe in the dust theory, no doubt it was the proper explanation of that accident—from a shot which had been fired on the main intake. With the Author's objections to shot-firing in coal he entirely concurred, and for these and other reasons he had promoted the use of the coal-wedge. At Tursdale Colliery sixty-four miners were now using it, with a great improvement in the proportion of large coal, and, of course, absolute freedom from danger; and, as the cost of using the wedge compared favourably with that of high explosives and of water-cartridges, it appeared to him to almost entirely obviate the necessity for using them in coal; their necessity had, in fact, ceased to exist; this referred not merely to long-wall working, but to the system of board and pillar. To the fact that water, when used with high explosives, would obviate their sudden and crushing effects, he could not at present assent, but would take an early opportunity of testing it in Cleveland Ironstone, where a slow rending action was an absolute necessity. His experience of the water-cartridge had not been large, but hitherto had been very unfavourable, on account of the cartridges bursting during insertion. With respect to the flame from a blown-out shot, he had found that not only was the tamping blown out, but the large grains of powder also, in a state of incandescence. The greater prevalence of mine explosions in the winter months, especially during intense frosts, might, he thought, be accounted for by the dryness of the air robbing the dust of its moisture in the main air-ways. The distilling action of the heat of explosion upon coal-dust, which of course produced gas, had not received the general attention it deserved; it met the objection, still raised by many persons, to the possibility of dust alone affording an explosion. In none of the experiments upon coal-dust did he find the question of the fineness of the dust sufficiently appreciated. Whether the dust from that or the other colliery was most explosive, seemed to him to be entirely dependent upon the fineness of the particles. He had employed the Liveing Indicator ever since its first invention, and considered that in the hands of the colliery manager, or good overman, it was a very valuable invention; but it was not suited to the hands of every rough experimenter; the test was a delicate one, and must always have careful, and to some extent skilful, manipulation.

Mr. Stokes. Mr. A. H. STOKES thought the Author, p. 38, appeared to question his remarks published in a Paper read before the Chesterfield and Midland Counties Institution of Engineers, namely, that the

excess of gas given off from goaves upon the sudden reduction Mr. Stokes of atmospheric pressure was carried away unnoticed. The Author had given an illustration, showing that for a diminution of 0·01 inch of barometric pressure, a goaf of only 1 acre in area and average height of 3 feet might part with about 44 cubic feet of its gaseous contents; but he had not mentioned the number of cubic feet of air in the ventilating current, which would probably have swept past the goaf during the fall of 0·01 inch of the barometer. However, supposing the barometer to have fallen 0·01 inch in five minutes—a very sudden fall—probably in most collieries there would have passed by the goaf 25,000 cubic feet of air in five minutes, and certainly 44 cubic feet of gas in 25,000 cubic feet of air would escape unnoticed. The references in Mr. Stokes' Paper were solely to accumulations of gas, and not to outbursts; and he considered the Author's remarks, vol. xc. p. 189 referring to "the majority of British coal-mines, which are now provided with ventilation amply sufficient to cope effectually with any such possible variations in the condition of the air in the workings," scarcely in unison with the criticism passed upon the comments named by the Author, *ante* pp. 38 and 39. The ventilation of a mine should always be far in excess of what was required, and beyond the reach of constantly recurring barometrical changes, having a surplus of air which would be more than sufficient to meet such emergency; and any mine in which the rise and fall of the barometer was the balance of safety should be considered unfit to be worked. With regard to the lime-cartridge and the "remarkable comments" published in the Transactions of the Chesterfield and Midland Counties Institution of Engineers, at the time those comments were penned he fully believed, from experiments which he had seen, that the lime-cartridge was a failure in the parts of a mine where such an appliance was most needed, namely, at the gate ends, or brushing, in the roadways; and at the present day he believed there was not a single coal-mine in the whole of the Midland district using the lime-cartridge, except Shipley Colliery, where the cartridge was made. The use of the lime-cartridge was not free from danger, as could be seen by reference to the accidents from its use, recorded in the Annual Reports of the Inspectors of Mines. He would also like to direct attention to the great difference between "bricklayers continually" handling "with impunity" mortar which had been thoroughly slaked and left without heat, and the collier handling caustic lime in the process of being slaked. He could only repeat the assertion, previously made, that the colliers loading coals in damp mines,

Mr. Stokes. where the lime-cartridge had been used, had to protect their hands from the effect of the unslaked lime; and even workmen in hot and dry mines, and perspiring freely, found the moisture of their hands caused the lime-dust to wear and eat away the skin, unless protected; and he repeated this assertion from actual investigation and from seeing and hearing the colliers themselves. Personally, he would like to have seen the lime process an unqualified success, for all and every case where explosives were used in mines; but he yet feared, in its present state, its successful application was only very limited for coal-getting or other mining operations.

Sir Frederick Abel. Sir FREDERICK ABEL, in reply upon the discussion and the correspondence, said he would in the first instance notice the criticisms of Mr. Bainbridge, that the subject of wedges had been incompletely dealt with by him; of Mr. Sydney Walker, that he had not discussed electric-signalling appliances; and of Mr. George Seymour, that he had confined himself to the consideration of accidents in coal-mines, to the exclusion of metalliferous mines. He would point out that, in the concluding part of the Paper, he had disclaimed any attempt even to deal completely with the comprehensive subject of accidents in coal-mines, having confined his subject to the most prominent only of the causes of accidents in collieries, and to the knowledge of those means by which their disastrous effects might be diminished. It would have been presumptuous in him, as an amateur in the study of mechanical appliances connected with this subject, to have criticised in detail the relative merits of different systems of wedges for coal-getting, or to have done more than give the conclusions arrived at by his colleagues on the Royal Commission and himself, from the evidence collected respecting the value of detaching hooks, of safety-hooks or clutches, and of other mechanical devices to guard against shaft-accidents. He might point out, however, that although he had not dealt separately with sources of accidents which might be peculiar to metalliferous mines, he had, in the first part of his Paper, incidentally discussed the subject of the employment of ladders, cages, and man-engines, in mines of that class to which Mr. George Seymour had referred. While concurring in Mr. Walker's view that the adoption of electric-signalling appliances in mines was attended with important advantages in underground work, he could scarcely regard them as being directly connected with the subject of prevention of accidents, and he had therefore omitted their examination.

It had been stated by Mr. Lupton that the danger of a goaf as a lurking place for firedamp-and-air mixtures "depended

upon two things, the depth of the mine and the age of goaf;" but, Sir Frederick Abel. surely, the possibility of danger from goaves was also closely connected with the question of the extent to which the old workings, where these goaves had been formed, were originally filled up, and the consequent degree of liability to the formation of large cavities, by the subsidence of large irregular masses of hard stone, which would not become filled up, in course of time, as assumed. Mr. Lupton dismissed the question of danger arising from accumulations of gas in goaves in a very facile manner, by saying that if the goaf was "properly ventilated, there was comparatively little danger." But it had been pointed out in the Paper that the great difficulty of dealing with the ventilation of goaves, in an effectual manner, constituted a most important and obvious source of danger; and that the possibility of connections being established between gas-laden cavities in the interior of goaves, and localities situated at no great distance from them where shot-firing was carried on, was also a probable element of danger in connection with imperfectly packed goaves, which merited grave consideration. This view of the importance of giving serious attention to the possibly intimate connection of goaves with many coal-mine explosions, had been confirmed by Sir Warington Smyth's remarks on this head; and the observations of Mr. William Morgans, who had done good service in carefully examining into this subject, were well worthy the consideration of Mr. Lupton. With respect to the inquiry made by that gentleman, as to whether there appeared to be any connection between the depth of a mine, and the pressure of gas in the coal of that mine, the results of the pressure-measurements referred to in the Paper as having been made in several coal-mines in the North of England and in South Wales, did not indicate any connection of that nature; thus, in one particular mine, the pressure of gas in a hole bored into the coal, at a depth of 2,400 feet, was 150 lbs. per square inch; while in another hole in the same mine, at a depth of only 900 feet, the pressure was 280 lbs. In a second instance, a pressure of 430 lbs. was recorded in a hole at a depth of 1,480 feet, while in a hole in the same mine 20 feet deeper, a pressure of 318 lbs. was indicated. It was also found that the direction of the hole, with reference to the cleavage of the coal, had no influence upon the gas-pressure indicated; and that, as mentioned in the Paper, several holes bored to different depths parallel to, and within a short distance from each other, gave very different maximum pressures of gas.

It had been suggested by Mr. Henry Hall that the late Commission should have given information as to the explosive

Sir Frederick Abel. force capable of being exerted by definite quantities of fire-damp; he stated that it was difficult to say how much gas was dangerous, and that officials treated the discovery of large volumes of gas here and there, during inspection, as being of no moment, saying that it was not dangerous. The Author could only reply that any statements, with regard to the explosive force capable of being exerted by different volumes of pure marsh-gas, would be of no practical value in reference to the possible destructive effects which roughly estimated accumulations of firedamp of unknown composition, in admixture with unknown proportions of air, might exert. The information, now widely disseminated, regarding the effects of dust (existing almost everywhere underground) in adding to and carrying on firedamp explosions, should, however, suffice to warn those entrusted with the inspection of mine-workings, that surrounding circumstances must indeed be most exceptional which would warrant the treatment with indifference of a considerable volume of gas, found in any part of a mine.

The observations of Mr. Lupton, with regard to the part played by coal-dust in mine-explosions, were good illustrations of the nature of arguments advanced by ardent advocates of the view that coal-dust alone was the cause of many explosions. There was some originality, however, in the view that if the results of analysis of the air of a mine in particular places demonstrated the existence in it of a small quantity of firedamp, there should be an inclination to discredit those results, because Mr. Lupton's arguments demonstrated, to his satisfaction, that no gas whatever ought to be found there. Other observations in the course of the discussion illustrated the diversity of views, still entertained by competent authorities, as to the sufficiency of the evidence, experimental and inferential, which had been advanced or collected in favour of the view that explosions originated with, and were carried on by, coal-dust in the complete absence of firedamp. Thus, Mr. Morgans had pointed out the insufficiency of evidence in the case of two explosions which had been ascribed to coal-dust alone, and Mr. Henry Hall, an eminent inspector of mines, who (without any detraction from Mr. Galloway's merits) had been the first to make experiments with coal-dust upon a scale nearly approaching in magnitude the condition of things existing in a colliery, while stating his conviction that explosions were greatly aggravated by the presence of coal-dust, had, at the same time, expressed his belief that no explosion had occurred in a mine of importance where there was no firedamp. On the other hand, Mr. Sawyer

had referred to a case in which, in his opinion, an extensive explosion had been caused by coal-dust, with probably only a "trace" of firedamp in the air. The opinion as to the probable amount of firedamp present was, of course, based upon the application of the usual (lamp-) test, which failed to detect less than 2 per cent. of gas, in the hands of experienced observers. This was an instance of the indefinite kind of information upon which the assumptions that no firedamp was concerned in particular explosions in dusty mines were always based, and which was not of a nature to combat the validity of the very definite statements advanced by the French authorities, Messrs. Mallard and Le Chatelier, namely, that all explosions of magnitude, in which dust had evidently played an important part, had occurred in mines in which firedamp existed; and that no explosion had been known to occur in lignite-mines, which were quite free from firedamp, although they were very dusty, the dust being highly inflammable. Mr. Beddington had, in the Author's opinion, expressed the rational view with regard to the coal-dust question, when he stated that, while he was not convinced that dust alone would serve to account for explosions of magnitude, which should be of very much more frequent occurrence if such were the case, he admitted that, where much dust was present, explosions were greatly aggravated thereby.

In the opinion of Mr. J. B. Atkinson the Author had not realized the full importance of the influence of coal-dust in colliery explosions. A perusal of the Paper would, however, show not only that the Author had there given the fullest weight to the facts and views contained in the Messrs. Atkinson's instructive work on Explosions in Coal-mines, but also that, after summarizing, he believed in a thoroughly impartial manner, the existing evidence and views regarding the part played by coal-dust (which he had to discuss in much greater detail in that part of the Royal Commissioners' Report which dealt with this subject), he had laid the greatest stress upon "the serious dangers arising from the existence of dust-accumulations in collieries," and upon the great importance of not "allowing any accumulation of dry dust to exist in workings where shots are fired." He had only argued (and in this action he was supported not merely by the writings of Messrs. Galloway, Atkinson, and others, but also by the observations which had been made during the discussion of the Paper), that the "serious dangers" liable to arise "from the existence of dust-accumulations in collieries," could certainly not become more impressed upon the mining public by the contention that particular explosions had been examples of "pure dust explosions," when all that could be

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Sir Frederick Abel, said in reference to the asserted freedom of the air in the mine, at the time of the explosion, from firedamp, was that it was practically free from gas, or that only traces of firedamp existed, or ought to have existed, in the air of the mine. Certain experiments of Mr. Hall, of Professor Marreco (to which Mr. William Cochrane referred), of the Author himself, and most recently of the Prussian Firedamp Commission, had demonstrated beyond doubt that explosions, of a more or less violent character, might be brought about by coal-dust possessing particular characteristics, in the complete absence of any trace of firedamp, and this had been clearly pointed out by him in the Paper; but those experiments also demonstrated as conclusively that a combination, in coal-dust, of the characteristics of extreme fineness of division, high inflammability and peculiar physical structure or condition, essential for the production of explosive effects and for very rapid transmission of flame, was very exceptional. Thus the "Leycett" dust, used in his experiments, the "Pluto" dust (and one other), with which the Prussian Firedamp Commission obtained, at Neunkirchen, violent explosive effects in the absence of firedamp, such as described by Mr. S. B. Coxon, were exceptional dusts among a great variety of fine, dry coal-dusts experimented with, many of which exhibited comparatively very little, or no, tendency to propagate flame rapidly and to a considerable distance, in the complete absence of firedamp, even when they were much more thickly suspended in the air than there would be any probability of their being in actual practice. The statement made in the communication from Mr. J. A. Longden, of Alfreton, a member of the Committee of the Chesterfield Mining Institute, by whom a most important series of coal-dust experiments had been carried out, afforded valuable confirmation of the truth of these observations. He stated that, amongst the very large number of dusts experimented with, there was "one particular dust, from the North of England," which "was highly explosive, without the addition of any gas whatever. On the other hand, none of the dusts from the neighbourhood of Chesterfield were nearly as explosive, and the dust from Blackwell Colliery could not be fired under any circumstances." Mr. Longden concluded, from the results of his special practical and experimental experience, that "there seemed to be an inclination just now to attribute to coal-dust more importance than, in the estimation of many mining engineers, the case deserved." Mr. J. B. Atkinson's criticism of the Author's statement that experimental results, of more or less exceptional character, or obtained under conditions which did not approximate to those likely to occur in a mine, was

answered, not only by the foregoing facts, but also by the illustration which Mr. Galloway's communication furnished, of the unpractically exceptional combination of circumstances which had attended some of the experiments made in support of the so-called "pure coal-dust theory," when, with the return-air of a mine, the freedom of which from firedamp was not maintained, the air required to be literally black with dust before it would ignite.

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In order to favour the pure coal-dust theory, it became necessary (as was done by its advocates), while admitting that firedamp existed in the air of most mines, to dismiss it in special instances, as a "trace" (which it was assumed to be upon theoretical considerations), and therefore, of no account as a factor in the origination or the development of explosions. This was a method of dealing with it not warranted by the results of experiments, nor by the fact that it had hitherto been the custom to consider the air of a mine free from all but "traces" of firedamp, when it had not furnished indications of gas by means of the safety-lamp test, but which might nevertheless contain at least 2 per cent. of gas. Mr. W. N. Atkinson's statement, that "it would probably not be difficult to prove by means of Liveing's indicator, or the Pieler lamp, that the large volumes of air passing along the main intake air-ways of such collieries did not contain even the very minute quantities of firedamp which these instruments were capable of detecting," suggested an obvious direction in which the advocates of the pure coal-dust theory could seek for positive evidence in support of their views. At the same time, the Author would not desire to suggest that further labours in this or other directions, with the object of supporting particular theories regarding the precise manner in which coal-dust operated as an element of danger in mines, would serve the least practically useful result; for while, on the one hand, both the possibility of serious explosions being caused in mine-ways and workings, where the air might be assumed to be absolutely free from firedamp, by the existence in abundance of coal-dust, possessing certain essential characteristics, and also the very exceptional occurrence in coal-mines of a sufficiently abundant supply of dust possessing those characteristics, had been thoroughly demonstrated, the serious dangers arising, in other ways now well known, from any kind of dust-accumulation in coal-mines, had, on the other hand, been not only conclusively established and elucidated, but had also become fully recognized by the mining community and officially, and means both practical and effectual had been prescribed for avoiding or diminishing those dangers. He considered that, in the present state of knowledge, it

Sir Frederick Abel. would have been unreasonable to provide, in the recently passed Act, for the systematic damping of coal-dust in all parts of dry mines, which Mr. W. N. Atkinson seemed to think should have been done ; but that the prescription of precautions, to guard against the ignition of coal-dust during shot-firing, must certainly be regarded as one of the most important improvements effected by that Act ; and it had been very satisfactory to have learned, in the course of this discussion, the nature of several efficient means of damping coal-dust in mines which had already been elaborated and applied, and which were obviously susceptible of further important development.

It had been stated by Mr. J. B. Atkinson that his experience pointed in a direction opposed to the accepted fact, mentioned by the Author, that the combustion of a mixture of air with a finely-divided inflammable solid was gradual in comparison with that of a mixture of inflammable gas and air ; but Mr. Atkinson had unfortunately not given the nature of his experience. On the other hand, he had mentioned several conditions under which he conceded that the Author's statement would hold good, and the argument advanced in favour of his view, upon which he appeared chiefly to rely, was embodied in the statement that, while the "rapidity of combustion of a homogeneous gas-and-air mixture probably reached its maximum within a short distance of the point of ignition," the "reverse was probable in the case of a coal-dust-and-air mixture." The Author would venture to ask whether this statement did not point to the conclusion that the transmission of flame by the gas-and-air mixture was the more rapid of the two ?

It was to be regretted that the labours of some of those who had contributed to a recognition by the mining public of the dangers of coal-dust, had, by developing in those workers a tendency to place it in a pre-eminent position among the elements of danger existing in collieries, led to a depreciation by them of the dangers due to sudden outbursts of gas, which had been so forcibly, but certainly not too seriously, dwelt upon by Sir Warrington Smyth, and also by Mr. R. Beddington, and to the accumulation of gas in, and its emission from, or possible explosion in, goaves, which Mr. Morgans had so lucidly discussed. That such was the case, however, must be evident to those who would peruse some of the observations elicited by the Paper. Without assenting to the remarks, made by Mr. Stokes, which tended to the dangerous inference that the possible escape of gas into the main-air from accumulations in goaves could not be matter for serious consideration, he feared that many mine-owners

and managers would not consider that the conditions to be fulfilled by the ventilation of a mine, as laid down by Mr. Stokes, were such as they should be compelled to comply with. Sir Frederick Abel.

The particular source of accident to which Mr. Edward Combes had directed attention, namely, the occasional escape into workings of choke-damp, or carbonic acid gas, from goaves or other lurking places, had received the consideration of the late Commission; but no other means could be suggested of guarding against its dangers than the constant careful inspection of localities liable to be invaded by escapes of the poisonous gas, the presence of which fortunately was indicated by its effects upon the flame of a lamp or candle before it could exert its deadly action. The maintenance of powerful air-currents, in localities liable to be infested by it, was an obvious precautionary measure, and the observations of Mr. Max Georgi on the importance of supplementing the regular system of ventilation by a system of auxiliary ventilation, and on the course of action taken by the Saxon Government in reference to this important additional safeguard, well merited consideration in especial regard to the dangers of choke-damp.

Sir Frederick Abel did not think that the remarks made by Mr. Harries, in support of his view that accidents were most prevalent during anticyclonic disturbances, needed any addition by him to the observations made in the Paper, in respect to the extent to which importance could be attached to the various views advanced regarding the connection between atmospheric disturbances and coal-mine explosions. Mr. Sawyer had made some very cogent remarks, in which he entirely concurred, in support of the conclusion, that it was idle to attach importance to attempts to establish a regular connection between barometrical variations and colliery explosions. Variations in dryness and in temperature of the external atmosphere might, on the other hand, in the present days of powerful ventilation, influence considerably the magnitude of explosions, in reference to the great influence of moisture upon the inflammability of coal-dust.

In referring to the increase of accidents due to falls of coal and stone in mines, Mr. Bainbridge had pointed to what certainly might be considered as one probable cause, namely the gradual exhaustion of seams having the best roofs, and the consequent increase in the work done in seams with insecure roofs. Sir Warrington Smyth had laid stress upon the importance of providing the miner with a good light; and the Author felt bound to state that, while he concurred with Mr. Henry Hall in his view that too much importance had been attached to the provision of a large

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amount of light by the lamps furnished to miners (especially as regarded miners' electric lamps), he must point out that he certainly had not advanced the obviously untenable view assigned to him by Mr. Hall, that falls of roof would be less frequent if the men had better light than was now provided. What he had maintained was, that casualties from falls would be diminished, if the men could apply sight in addition to ear in judging of the degree of imminence of danger threatened by a coming fall.

The information which he had brought before the Institution in his Paper respecting recent improvements in the construction of safety-lamps, and the progress made in the application of electricity to the illumination of mines, had been very usefully supplemented by the interesting exhibition of recent work in these directions.

Some points had been referred to in the discussion with respect to general details of construction in lamps of modern types, a few of which he would briefly notice. He concurred in Mr. Bainbridge's view, that a lamp which could be confidently depended upon as safe in a current velocity of 30 feet per second, was for all practical purposes a safe lamp in most mines, and that many designers of new lamps had fallen into the error of resorting to very complicated and costly arrangements, for enabling their lamps to withstand exceptionally severe tests. Such lamps presented the additional defect that they were heavy, and that their various parts were difficult to put together properly, so that reliance could not, especially in the absence of a gas-test, be placed upon their reaching the miners' hands in a safe condition. The most recent lamp of Mr. Bainbridge's construction certainly possessed the merit of simplicity; the readiness with which it could be cleaned and the arrangement for leaving the glass untouched, were very good points.

It would certainly not be found by Mr. Hall that the Author had especially recommended lamps with glasses; he had distinctly stated that, although such lamps were obviously superior in point of efficiency as illuminating agents, they were open to objection on the score of uncertainty of safety which the glass presented; and he had gone into considerable detail with respect to the various possible causes of the doubtful safety of such lamps, even when provided with double glasses. Sir Warrington Smyth had referred to two unquestionable drawbacks presented by the hood or "bonnet," with which the majority of modern lamps, from the Marsaut to Mr. Bainbridge's latest lamp, were provided. The additional heating of the lamp, due to the retention of heat by the metal

envelope surrounding the gauze, was no doubt a source of occasional inconvenience; but the more substantial objections were that the bonnet prevented the men from seeing what was going on inside the gauze, and also obstructed the distribution of light above a certain plane, so that the roof of a road or working was even more imperfectly illuminated than by the old gauze lamps. The first of these objections was not difficult to remedy; by cutting two narrow slots opposite to each other, in the bonnets, and fitting these with mica plates, which could be easily done, small windows could be provided, through which all that took place inside the enclosed gauze cage could be readily seen, and the protection afforded by the bonnet would not in the least degree be diminished. He had fitted several bonneted lamps in this way, for the purpose of seeing how they behaved in powerful currents of explosive gas-mixtures, and the arrangement answered perfectly. The obstruction of light in the upward direction was inevitable, and this was undoubtedly a sacrifice in efficiency, which, however, was considered as more than compensated by the safety which the use of the bonnet secured. At any rate, the most experienced lamp-makers, such as Messrs. Bainbridge, Ashworth, and Marsaut, like other inventors of new forms of lamps, mostly adopted the hood or bonnet as an essential element of safety. Mr. Sawyer, one of H.M. Inspectors of Mines, had said that even Mueseler lamps should be fitted with bonnets, which should be easily movable, to facilitate the examination of the gauze by the fireman, and the Author believed that the bonneted Marsaut lamp had come into extensive use in some districts, with no inconvenient results, the superior illuminating power of the lamp compensating for the partial obstruction of the light in the upward direction.

Members of the Institution had an opportunity afforded them, by the interesting exhibition of lamps of various kinds in the building, of forming some judgment for themselves whether he had been too sanguine in predicting that the safe and thoroughly efficient application of electric light to the purposes of the miner would speedily be accomplished. How far the cost and the weight of self-contained miners' electric lamps would be susceptible of sufficient reduction, to bring them thoroughly into competition with safety-lamps of the best modern types (for they would scarcely be likely to compete with the older forms of lamp in these respects), would probably be determined within a brief period. Certainly the present original cost of the secondary battery in lamps was prohibitive, as pointed out by Mr. Tylden-Wright; while their weight, although it had been

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already considerably reduced, was still inconveniently great. On the other hand, the lightest of the improved forms of safety-lamps were at least double the weight given by Mr. Tylden-Wright as that with which the electric lamps had to compare. He could not agree with the view, taken by Mr. Sydney Walker, that the eventual method of applying electricity to the illumination of the face of the coal would be by supply-mains, or main conductors. The objections to fixed lights, and to the attachment of lamps to main-conductors by branch wires, had been pointed out in the Paper. Those objections appeared to counterbalance the advantages to be secured, and they were not met by Mr. Walker. Moreover, the lamp which gave light to the miner for his work should also be available for lighting his path to and from work, the distances to be travelled rendering the illumination of the mine-roads throughout generally quite out of the question, from the point of view of cost alone. As to difficulties in the application of secondary-battery lamps, at collieries where electric-light installations already existed, consequent upon necessary complications of arrangement, he could assure Mr. Walker that practical experience had already given a satisfactory answer in the negative to this supposed objection. The chief advantages, at present possessed by such primary-battery lamps as had assumed a practically useful form, consisted in their comparative lightness and their lower cost. Mr. Tylden-Wright and Mr. J. A. Longden had pointed to two important objections to the general use of electric lamps to the exclusion of ordinary safety-lamps; they afforded to the miner no means of warning him of the existence of foul air or choke-damp, nor could the air of the mine be tested for the presence of firedamp by their means. There appeared at present no mode of meeting the first objection; with respect to the second, he had pointed out that Mr. Swan had already applied an electric gas-detector as an adjunct to his miners' lamp; it remained to be seen whether this would furnish a reliable and readily applicable substitute for the safety-lamp or other more sensitive gas-detectors now known.

It having long since been generally acknowledged that some more sensitive indicator of the presence of firedamp than the Davy lamp, or such other forms of safety-lamp as were preferred by some for inspecting purposes, was much needed, he had felt some surprise that Mr. Lupton should have dismissed the subject of gas-indicators by a reference only to the earliest instruments of this class, the Ansell indicators, which had long been well known to possess radical defects, as pointed out in the

Paper. Mr. George Seymour had also summarily dismissed the subject of gas-indicators generally with the statement that "experience" had demonstrated them to be of but little practical use; but he had not even mentioned the kind of indicators of which he or others had acquired this unfavourable experience. He was glad to find, on the other hand, that Mr. Steavenson had spoken of the Liveing gas-indicator, from personal experience, as a very valuable instrument in the hands of a good overman. He felt convinced, from his own experience, that this instrument would not be at all difficult to use after very little practice; and he could assure Mr. Hall that the handle, which actuated the arrangement for heating the little test-coils, did not require to be turned at a certain fixed speed in order to furnish uniform results. He felt confident that, for purposes of special inspection, at any rate, this gas-indicator would be a valuable acquisition; and he believed that a form of eudiometrical gas-detector would also ere long be perfected as a reliable instrument. It could scarcely be denied that, while the skilful use of particular varieties of safety-lamp furnished the means of detecting small percentages of firedamp in mine-air, it was desirable that overmen or firemen should be furnished with, and become accustomed to the use of, apparatus by which very small proportions of firedamp could be detected, and their amount estimated with considerable accuracy. It had been thoroughly well established that a proportion of firedamp in the air, which would altogether escape detection by means of a safety-lamp, might constitute an element of great danger in dry and dusty mines.

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In referring to the subject of safety-lamps, Mr. Tylden-Wright had defended the alteration, made in the House of Lords, of the general rule relating to safety-lamps, which, as adopted by the House of Commons, excluded "unprotected" Davy, Stephenson, and Clanny lamps from the category of safety-lamps, and Sir Frederick Abel was surprised to find Sir Warrington Smyth in agreement with Mr. Tylden-Wright on the subject, because when the former and the Author were Members of the Royal Commission together, Sir Warrington's views regarding the dangerous character of the unprotected lamps in question, when used in any part of a mine where only a very moderate ventilating current was met with, were so strong, that he had no hesitation in assisting in the preparation of a letter, addressed to the Home Secretary, on the 15th of December, 1880, which he signed as Chairman of the Commission, the object of this letter being to recommend that it should be made known as soon and as widely as possible, that

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"the employment of the ordinary Davy lamp without a shield of metal or glass, in an explosive mixture, when the current exceeded 6 feet a second, is attended with risk of accident almost amounting to certainty. The Clanny lamp, when tested in a similar current, has proved to be scarcely, if at all, less dangerous."¹ Moreover, in the unanimous final Report of the Commission, presented in March 1886, the following statements were made²:—"It results then, from the improved ventilation of mines, that if the current becomes sufficiently charged with firedamp, the Davy and Clanny lamps" (which are frequently exposed to current-velocities of from 20 to 25 feet per second in the air-ways, and might occasionally be exposed to currents having velocities of from 30 to 35 feet per second) "cease to be in any way safety-lamps, and the Stephenson (Geordie) lamp may often cause an explosion." After having stated that the "insecurity of these lamps" had been conspicuously shown by the results of the Commission's experiments, and had previously been demonstrated by various Societies of Mining Engineers, the Report proceeded:—"Under present conditions as to ventilation, the danger of relying upon Davy and Clanny lamps seemed to us so great that we felt it our duty, at an early stage of our investigations, to address a letter to the Secretary of State for the Home Department, calling his special attention to the insecurity of these lamps." He could not comprehend on what grounds a simple reiteration, though in less emphatic terms, of this condemnation of unprotected Davy and Clanny lamps, of which Sir Warrington Smyth was joint Author, was characterized by him as an "onslaught" on these lamps. Nor could he understand what the exclusion of unprotected Davy, Clanny, and Stephenson lamps from mines where it was necessary to use safety-lamps, had to do with mines in "many districts in the country where no gas had been perceptible from generation to generation," and where, therefore, naked lights would still, as hitherto, be used without any interference. As regarded such mines, which, according to the late Chairman of the Commission, "were scattered broadcast throughout the land, as in the Forest of Dean, South Staffordshire, and other districts," where "gas was never noticed," the retention of the House of Commons Clause, with respect to unprotected lamps of the kind specified, would certainly not have led to any dictation to the people work-

¹ Accidents in Mines, Final Report of Her Majesty's Commission, 1886, p. 188.

² *Ibid.*, p. 67.

ing in them to "take some new patent lamp capable of with- Sir Frederick Abel.
standing the effect of a strong current," as there was certainly nothing in that clause to enforce the use of lamps in place of naked lights, where no gas had ever been noticed. The Commons' Clause did not even prohibit the use of Davy and Clanny lamps in any mine, but only insisted that they should be protected; and no one knew better than Sir Warrington Smyth, from the large number of experiments in which he had taken part, as well as from the practical trials he had witnessed, that these lamps, which he had considered it his duty to condemn as unsafe, could be protected by very simple and inexpensive adjuncts, and had been so altered in very large numbers by mine-owners, so as to render them as safe in the highest current-velocities ordinarily met with in mines at the present time, as they were in the first days of their invention, when only currents of very low velocity existed underground, and thus preventing their exclusion by the terms of the general rule, either as it now stood or as it was approved of by the House of Commons. Mr. Sawyer had pointed out that, in the district in which he was Inspector, unprotected lamps were rapidly disappearing in all fiery mines; but there might be districts in which such action, being purely at the option of the mine-owners, managers, or men, might be neglected, or very difficult to enforce, in consequence of the ambiguous wording of the general rule as it now existed, and of the ardent advocacy of the lamps in their original state by such influential gentlemen as Mr. Tylden-Wright.

That gentleman had said that nothing could be more definite than the present clause in the Act relating to safety-lamps, as amended by the House of Lords; but he went on to show that intelligent men (under which head the Author ventured to couple himself with Mr. Tylden-Wright) might put two very different constructions upon it, and thus to demonstrate the obvious ambiguity, as pointed out by him, of that passage in the rule which spoke of "that part of the mine in which the lamps are for the time being in use." Sir Warrington Smyth well knew that currents of exceptionally high velocity might occasionally be encountered by men carrying unprotected Davy or Clanny lamps in mines in which "the current ordinarily prevailing" would not involve danger, and Mr. Sawyer had directed attention to the important fact that the safety of an unprotected gauze lamp, "when it was carried against an inflammable current of the smallest velocity, depended entirely on the rate at which the person who was carrying it was

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travelling," and that "this varied much and could not be regulated." A stronger argument in favour of the wisdom of the course which the House of Commons had agreed to adopt could not well be imagined, and Mr. Sawyer had aptly illustrated it by reference to a recent accident, which was ascribed to a Davy lamp, carried by a collier, who was hastening at the time in a direction contrary to an inflammable current which had, at the place and time of the explosion, a velocity of only 2 feet per second. He would commend to the notice of Mr. Bainbridge this accident, as being only one of several due to lamps which, in his comparatively brief experience, he had heard of.

As a man of science and a chemist, he could not yield to Mr. Tylden-Wright in his admiration of Davy, and of his beautiful researches which led to the construction of his safety-lamp, but could not admit that his great name would come under any "obloquy," because the Davy lamp, in its simple original form, was no longer the safe lamp which it undoubtedly was for many years after its first introduction, until other important advances in applied science had altered the conditions which presented themselves to Davy as those to be met by a safety-lamp. But it appeared that, after all, Mr. Tylden-Wright was mainly desirous of retaining the unprotected Davy lamp in use, not for the general purposes of the miner, but because it was looked upon in South Staffordshire as the most delicate and best practical apparatus for testing for gas in mines. Mr. Tylden-Wright was, perhaps, not aware that a protected Davy lamp could be most easily taken out of its case, when the fireman arrived at a place in a mine which had to be examined for gas; but even this was unnecessary, for Sir Warington Smyth had stated, upon the high authority of Mr. Lindsay Wood, that the protected, or cased Davy, which stood very well in point of safety in the Commission's experiments, and was, indeed, thoroughly safe for all ordinary conditions, could be as readily and effectively used for testing purposes as the unprotected lamp. He was glad that reference had also been made, by Sir Warington Smyth, to the fact that competent practical authorities were by no means in accord in accepting the Davy lamp as the most sensitive lamp for purposes of inspection. Mr. Sawyer's published experiments, which were very complete, had established the superiority of the Mueseler lamp, which had been confirmed by Messrs. Mallard and Le Chatelier; while Kreischer and Winkler had been led by long experience to give the preference to lamps of the Clanny and Boty types. Mr. Sawyer had also stated, and no one was more competent to know than he, that men

who had become used to the Mueseler lamp were now as wedded to it as they had been to the "Old Davy," and that no difficulty was experienced, after its use for a short time, in carrying it even in steep mines without fear of its being extinguished. Too much importance must, therefore, not be attached to Mr. Tylden-Wright's local experience, as to the unprotected Davy being indispensable; no doubt it was so considered by those who had always been accustomed to use it, but in several collieries the men who had been wedded to it were now equally attached to the cased Davy. He therefore maintained, against Mr. Tylden-Wright, and even against so high an authority as Sir Warrington Smyth (whose own words, however, had strongly supported his contention), that the prohibition of the dangerous "unprotected" lamps, which was all that was contemplated by the House of Commons' general rule, would neither have dimmed in the least the lustre of Davy's name in connection with his safety-lamp, nor have resulted in any hardship to those who had hitherto used the unprotected lamps.

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He would assure Mr. Tylden-Wright that he was quite aware of the fact that hundreds of collieries in the United Kingdom were at a long distance from gas-mains; but he could also assure him that, if a gas-test for lamps had been established by law, there would have been no difficulty in providing, at little outlay and trouble, for the maintenance of the small gas-supply necessary for the systematic application of the test to the lamps in regular use. The bearing of Mr. Lupton's observations, with reference to the value of a gas-test for lamps, was difficult to fathom; he would only state that the value of such a method of testing, and the feasibility of applying a reliable and searching gas-test, were beyond question, and he felt confident that Mr. Lupton would have no difficulty in himself arranging such a gas-test as would furnish that check "upon the eye and skill of the lamp-man," which even the most implicit trust in that official rendered highly desirable.

There could be no doubt, as pointed out by Sir Warrington Smyth, that blown-out shots, which had been a fruitful source of accident, and the starting-point of many serious explosions, were far more frequent than they should be in coal-mines, if more knowledge, skill, and care were brought to bear in the selection of the spot for the charge of explosive, the placing of the hole, the process of charging, and the adoption of simple measures for facilitating the operation of the charge. The neglect to hole and cut the coal at the fast-places before shot-firing, and the bad

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Mr. Sawyer as constantly conducing to the occurrence of blown-out shots, and of consequent accidents. So long as knowledge and intelligence were not brought to bear on these important points, there was little hope of a general realization of Mr. Bainbridge's picture of the present freedom from risk of serious accident in well-regulated mines, from the occurrence of blown-out shots. Mr. Bainbridge had expressed his belief that the use of certain explosives of recent invention, such as roburite and carbonite, would have the effect of putting an end to the dangers arising from blown-out shots, and based his favourable opinion of the first of those materials upon the personal observation of a single "blown-out shot" underground, from which he saw no sparks produced. Sir Frederick Abel had repeatedly seen the same result with other explosives, which were not, however, invariably confirmed in repetitions of the trials; and that the same was the case with roburite had been demonstrated by experiments in this country, which had been noticed in the public prints, and by experiments in Germany. Thus, in some official trials at Neunkirchen, two charges of about 8 oz. of roburite had been fired, as blown-out shots, into atmospheres containing 6 per cent. and 8 per cent. of fire-damp. No explosion occurred in either case, but in two repetitions of the trial in the firedamp and air-mixture, a violent gas explosion was produced in each case by the blown-out shot. He had given reasons in the Paper (p. 59) why the explosive carbonite, to which Mr. Bainbridge had also referred, could not be expected to secure immunity from the dangers due to blown-out shots, and there was no reason to believe that securite, nor any other high explosive, applied *per se* in a shot-hole, could be relied upon to secure freedom from the projection of matter sufficiently highly heated to ignite an explosive gas-mixture, when a blown-out shot was produced.

That the principle of cooling down the incandescent or highly-heated matters projected by a shot, by means of water, applied in one way or another, was now receiving beneficial application in connection with shot-firing, was a source of great gratification to him. He had, as Sir Warrington Smyth kindly pointed out, laboured quite disinterestedly to bring to bear, as a safe and efficient method of working in coal, the system of distributing the explosive force exerted by a detonated charge through the agency of water, by which it was completely surrounded, which he had elaborated fifteen years ago. He felt sure that if Mr. Tylden-Wright would pursue experiments a little further, he would find that certain nitroglycerine preparations, such as gelatine-dynamite, would, through

the agency of water, do work in coal quite equal to that performed by powder used in the ordinary way. He should add, in reference to a suggestion of Mr. Tylden-Wright, that it would be labour thrown away to endeavour to ensure safety in the use of powder through the agency of water. This matter had been thoroughly dealt with in the report of the Commission. The only objection to the water-cartridge which had been raised was that mentioned by Mr. Hall, and by Mr. A. L. Steavenson, namely, the weakness of the water-bag or envelope; this certainly did not exist in any form of cartridge which he had used, and was easily guarded against. Mr. Sawyer had wisely pointed out that care and intelligence were necessary to ensure success, with the use of the arrangements for blasting in conjunction with water, as in any other operation needing attention to simple precautions. He was glad that Mr. Forster Brown had successfully employed, and had acquired confidence in, the comparatively simple method of using water in conjunction with a porous body, such as moss, of the efficiency of which, in conjunction with high explosives, the Commission had been led by experiment to entertain a high opinion.

Proposals, which had been repeatedly made, to apply as tamping materials, substances which contained water or carbonic acid, or both, in considerable quantities, and which parted with those constituents more or less readily when exposed to heat, had been commented upon by the Author as possessing no value from the point of view of promoting safety in coal-blasting, because the extremely brief period during which portions of such tamping would be exposed to heat, upon the firing of the charge of explosive in rear of them, would be altogether insufficient to expel a quantity of either aqueous vapour or carbonic acid from them, adequate to exert any effect in extinguishing, or materially reducing the temperature of, the highly heated products of explosion or of projected flame and sparks. He had much desired to test the correctness of his views by the results of actual experiment, and since the reading of the Paper he had succeeded in doing so. A large cast-iron shell had been compactly filled with powdered soda crystals, a cavity being afterwards made in the centre, for the reception of a charge of gunpowder. The shell was closed with a metal screw-plug having a perforation through which a fuze was inserted into the charge. Upon exploding the latter, the shell was not burst, but the products of explosion gradually escaped through the perforation in the shell-plug. The crystallized carbonate of soda was therefore exposed to the heat, developed by the explosion, for a much longer

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period than it would have been had it been employed as tamping in a shot-hole and at once projected, by the rush of escaping gases, if the shot had blown out. A portion of the contents of the shell which was nearest to the gunpowder charge was found to contain 62·04 per cent. of water; a sample of the soda crystals with which the shell was charged was found to contain 63·25 per cent. The exposure of the salt to the heat of exploding gunpowder, under more severe conditions than those which obtained in the case of a blown-out shot, did not, therefore, expel a proportion of water sufficient to produce any practically useful effect in cooling down the products of explosion.

It was not improbable that a very different result would be obtained if a substance, containing large proportions of volatile constituents, such as soda crystals, alum, or an ammonium-salt, were intimately mixed with an explosive agent, in such proportions as not to interfere too greatly with the transmission of explosion or detonation through a charge of the diluted material; as in that case portions of finely divided crystallized salt, or volatile substance, would be individually exposed on all sides to the heat developed at the instant of the explosion, and the cooling effect, due to the conversion into vapour, and expansion, of the water or other readily volatilizable constituents, would be brought to bear upon the products of explosion almost instantaneously upon their generation. Experiments, which had been quite recently made in this direction in Germany, appeared to have furnished very promising results. Preliminary trials, conducted by the Rhenish dynamite company, with charges ranging from 8 to 18 oz. of a mixture of Nobel's No. 1 dynamite with finely-powdered soda crystals, by firing them as blown-out shot in a gallery containing an explosive gas-mixture with much fine coal-dust suspended in it, showed that only in one case, when the proportion of the salt that had been mixed with the dynamite was very small, was an explosion of the gas-and-dust mixture produced. The experiments were then taken up by Mr. Hilt, President of the late Prussian Firedamp Commission, and carried on in the large experimental gallery at Neunkirchen, with comparatively heavy charges of the soda-dynamite, it having been observed by Mr. Hilt, in the course of experiments with roburite, securite, and carbonite, that explosive gas-mixtures were seldom ignited by small charges, while they were generally exploded when heavier charges were used. Mr. Hilt stated that, so far as the experiments with this modified dynamite had been carried, the effect of glycerin with the soda crystals was to modify the violent action of

the original explosive, so as to assimilate the results which it furnished in coal-getting to those obtained with gunpowder. The experiments were still being pursued in Germany, and Mr. Max Georgi even went so far as to assert that the perfect safety of soda-dynamite (*Wetterdynamit*) had been quite established. At any rate, the results obtained appeared to the Author so important, in reference to the provision of an efficient blasting agent for use in coal-mines, which would not require any adjunct, or the adoption of any other than the ordinary method of charging holes, to ensure perfect safety, that he was taking steps to carry on searching experiments with it, the results of which he hoped ere long to communicate to the mining public.

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The conflicting nature of the observations made in the course of the discussion, and in the correspondence, with regard to the merits of wedging, and of lime-cartridges, when employed as substitutes for gunpowder in coal-getting, seemed to show that the important and really obvious fact was frequently lost sight of, that neither of the two systems was calculated to do the same character of work in different varieties of coal, and that neither the inventors of particular forms of wedges, nor the elaborators of the compressed lime-cartridge, maintained that the explosive agent could be replaced by either in working all descriptions of coal. The somewhat extreme views of Mr. Stokes with regard to inconveniences and supposed dangers, attending the use of lime-cartridges, were evidently not shared by Mr. A. R. Sawyer, whose observations on this subject, also based upon personal knowledge, had, on several important points, confirmed the conclusions arrived at by the late Royal Commission.

In answering the various questions raised in the course of the discussion, he had endeavoured to deal separately with each important subject on which it appeared necessary for him to comment and reply, and in order to do this thoroughly he had included in those replies the consideration of some of the communications of correspondents. Mr. Forster Brown had supplied interesting information on some other matters included in the Paper. With regard to his remarks on the subject of goaves, they appeared after all to admit that extensive accumulations of gas might occur in these. Mr. Coxon's account of the experiments with dust, which he had witnessed at Neunkirchen, confirmed the statements made in the final report of the Royal Commission respecting the experiments of the Prussian Commission. With regard to his description of an explosion, which he ascribed purely to dust, the assumption that this was so was open to the objection that he assumed the absence

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It was well known that Mr. J. Ashworth had devoted much labour to effecting improvements in safety-lamps, and those described by him would doubtless, like that of Mr. Bainbridge, receive the attention of mine managers. Mr. Forster Brown was one of the few practical men who could already speak from somewhat considerable experience of the value of electric light in mines, and it was satisfactory to find that he looked forward with confidence to the speedy provision of thoroughly efficient self-contained lamps. As regarded fixed lamps, he did not appear to contemplate the future extension of their use beyond the main haulage roads, while Mr. Arthur Sopwith shared the view advanced by Mr. Sydney Walker, that the future would see electric light applied to the face of the coal through the agency of main conductors, rather than by means of self-contained portable lamps. Mr. Sopwith made light of the objections which the Author had raised against the attachment of lamps, required at the working places, to main conductors by branch wires; but he did not suggest how these necessarily very light leads were to be protected from the liability to injury by falls of coal or stone and rough usage, to which Mr. Longden and Mr. Sennett had referred. The whole question of the application of electric light underground had, however, only passed through the first stage of its development, and there was no doubt that practical electricians would, with proper encouragement from the owners of mines, and by wholesome competition with each other, achieve successes which were at present only foreshadowed. The importance of bringing the cost of electric lamps within such limits as to allow of their competing, from an economical point of view, with safety-lamps of the ordinary and improved types, if any such really extensive trial was to be made of the new system of illumination as could alone lead to its thoroughly successful development, gave force to the observations made by Mr. Story-Maskelyne, which he would venture to commend to the consideration of those who, at present, controlled the supply to the public of the only form of electric light which was susceptible of safe application in coal-mines.

In conclusion, the Author would only say that he cordially agreed with Sir Warington Smyth in the observations he had made, and which were in harmony with those of several other highly com-

petent speakers, that the safe working of collieries must always be in a far greater degree dependent upon the experience, judgment, constant vigilance and care, of those entrusted with their management, and upon the intelligence and ceaseless watchfulness of the subordinate officials, than upon inspection by Government officials, however much it might be increased and elaborated.

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LIST OF SAFETY APPLIANCES, &c.,
IN CONNECTION WITH MINING,
EXHIBITED IN ILLUSTRATION OF SIR FREDERICK ABEL'S PAPER,
NOVEMBER, 1887.

DETACHMENT OF MINERAL FROM ITS BED.

	Contributors.
Bickford, Smith and Co.'s patent safety-fuze	{ BICKFORD, SMITH and Co.
Colliery lighters and coil	" "
Settle's patent gelatine water-cartridge.	{ NOBEL'S EXPLOSIVES Co.
Glass cartridge and three tin cartridge-cases	J. ROUTLEDGE.
Gelatinous compound for safety blasting	D. MUNRO.
Improved electric battery for shot firing in mines	M. SETTLE.
Shot-firer for lighting fuze for blasting purposes	"
Safety water-cartridge	"
Gelatine water-cartridge	"
Magneto-exploder	JOHN DAVIS and SON.
" " (for water-cartridge).	{ SIEMENS BROS. and Co.
Fire-extinguishing compound	G. TRENCH.
Model of tonite-cartridge surrounded by ditto	"
Displaced cartridge in tube of gelatine	"
Safety-lamp for lighting fuze	D. MUNRO.
Compressed lime-cartridges (Sebastian Smith and Moore's)	{ THE COMPRESSED LIME - CARTRIDGE Co.
Draw-wedge (Bell and Ramsay's)	W. RAMSAY.
Model of the Haswell Mechanical Coal-getter.	T. BELL.
" " " "	W. F. HALL.
Coal-getter	E. MOULD.

CARRIAGE OF MINERAL TO THE SURFACE.

Detaching hooks and safety-cages (King and Humble's).	S. HUMBLE.
Automatic gearing for preventing overwinding (model)	T. KIRKLAND.
Automatic arrangement for preventing overwinding (model)	} M. SETTLE.
Nicholls' safety-hook and hoist (model)	{ T. CLARKSON, Stud. Inst. C.E.
Walker's detaching hook to prevent overwinding	T. BELL.
Clip-pulleys (two models)	G. J. LAMPEN and Co.
West's simplex safety-link	" "

	Contributors.
Mining bells and tappers (two)	COX-WALKER and Co
Dome bells (two)	" "
Double semaphore and signalling-bell	" "
Single semaphore	" "
Signal-bell	G. J. LAMPEN and Co.
Electric signal-bells and keys	{ S. F. WALKER (Assoc. M. Inst. C.E.) and OLLIVER.

DIFFICULTIES ATTENDANT ON THE PRESENCE OF GASES, EXPLOSIVE OR OTHERWISE, AND OF COAL-DUST.

Barton's respirator.	G. J. LAMPEN and Co.
Respirator	" "
Fleuss apparatus for working in noxious gases	SIEBE, GORMAN and Co.
Loeb's (J.) respirators, several sets	{ THE MARITIME AND GENERAL IMPROVE- MENT CO.
Apparatus for testing the presence of carbonic acid in mines	{ C. LE NEVE FOSTER.
Garforth's firedamp detector	{ J. D. THOMAS, Assoc. M. Inst. C.E.
Ashworth, Hepplewhite-Gray, and other lamps for testing firedamp (stand of six)	{ J. ASHWORTH.
Self-turning and other Biram anemometers (ten)	JOHN DAVIS and Son.
Biram anemometers (two)	{ J. DAGLISH, M. Inst. C.E.
Dickinson anemometer	"
Self-recording aneroid barometer	"

DIFFICULTIES ATTENDANT ON THE NECESSITY OF ARTIFICIAL LIGHT.

Safety-Lamps, oil and spirit.

Safety-lamp.	C. F. CLARK.
Marsaut (Mill's)	W. CLIFFORD.
Smethurst's.	"
Mercier's	"
Davis's	"
Bonneted Clanny	"
W. Morgan's new	"
Jack lamp	"
Evan Thomas' No. 7	"
Barrow-Hematite Mueseler	"
Aldwarke Mueseler	"
Davy lamp, 1813	{ S. B. COXON, M. Inst. C.E.
Bonneted Clanny (two)	JOHN DAVIS and SON.
Mueseler (three)	" "
Marsaut (four)	" "
Davis-Ashworth Mueseler (two).	" "
Deputies' and fire-tryers' lamp	" "
Marsaut dialling lamp with Stokes' shut-off	" "

	Contributors.
Douglas' self-extinguishing	J. DOUGLAS.
Evans' self-extinguishing (two)	E. EVANS.
Davy, manufactured about seventy years ago	W. F. HALL.
Davy encased (three)	"
Hann's, lighted by the aid of electricity without un- locking	E. M. HANN, M. Inst. C.E.
Bonneted Davy	J. LAIDLER.
Safety	G. J. LAMPEN and Co.
Mueseler	" "
Safety Porch lamp	" "
Morgan	W. MAUER.
Marsaut	JOHN MILLS and SONS.
Donald	"
Pittuck	F. W. PITTUCK.
Routledge and Johnson combined double safety (two)	J. ROUTLEDGE.
Davy, protected, newest pattern, Haaswell Colliery (two)	Sir WARINGTON W. SMYTH.
Miner's	EVAN THOMAS and WILLIAMS.
Fireman's	" "

Safety-Lamps, electric.

Edison-Swan (six) portable	{ EDISON-SWAN UNITED ELECTRIC LIGHT Co.
Pitkin (two)	J. PITKIN.
Rees	J. P. REES.
Schanschieff (six)	A. SCHANSCHIEFF.
Sennett, ...	{ A. R. SENNETT, Assoc. M. Inst. C.E.
Thomson	W. B. THOMSON.
Urquhart	D. URQUHART.
Walker and Olliver (two)	{ S. F. WALKER (Assoc. M. Inst. C.E.) and OLLIVER.
Settle (six) fixed	M. SETTLE.
Glow lamp-holders	COX-WALKER and Co.

MISCELLANEOUS.

Accidents from falls of roofs and sides (two series of illustrations)	{ A. R. SAWYER.
Coked coal-dust from the Walker Colliery after an explosion	{ J. B. ATKINSON.
Coal-dust from the Arley Seam, Wigan	H. HALL.
Corf and corf greaser (model)	G. J. LAMPEN and Co.
Horn's tachometer	S. HUMBLE.
Improved indicating oil-cistern	G. J. LAMPEN and Co.
Machine for plugging lead lock-lamps	JOHN DAVIS and SON.
Machine for moulding lead rivets	" "
Ochwaldt pressure-gauge for regulating atmospheric currents in mines	{ THE MARITIME AND GENERAL IMPROVE- MENT Co.

	Contributors.
Photographs of flame from dynamite cartridges incorporated with materials of Schönweg's patent	E. SPON, Assoc. M. Inst. C.E.
Screen wire	G. J. LAMPEN and Co.
Telescope dial with Hoffmann head.	JOHN DAVIS and SON.
Water-gauge	J. DAGLISH, M. Inst. C.E.
Working of mines (16 series of photographic views)	A. SOPWITH, M. Inst. C.E.

22 and 29 November, 1887.

GEORGE BARCLAY BRUCE, President,
in the Chair.

The discussion, upon the Paper by Sir Frederick Abel on
"Accidents in Mines," occupied both evenings.

6 December, 1887.

GEORGE BARCLAY BRUCE, President,
in the Chair.

The following Associate Members have been transferred to the class of

Members.

JOHN AUDLEY FREDERICK ASPINALL.
WILLIAM TREGARTHEN DOUGLASS.
WALTER FAITHFULL GARLAND.
HENRY ALEXANDER JAMES.
HENRY KEATING, M.A.
JAMES BRADDON MCCALLUM.

CHARLES ROBERT MANNERS.
JOSEPH MITCHELL.
WILLIAM PELHAM RICHARDSON.
FREDERIC HENRY READ SAWYER.
BRENTON SYMONS.

The following Candidates have been admitted as

Students.

JOHN SIDNEY ALFORD.
PIERCIE SEVERN ANDERSON.
ERNEST ANSON.
STANLEY CLAUDE BAILEY.
CHARLES WEATHERALL BAKER.
CHARLES VINCENT BELLAMY.
OTTO LEOPOLD BERINGER.
JOHN BENJAMIN BODY.
HILERSDEN BULTEEL.
HERBERT CHARLES CHAPMAN.
THOMAS HOWARD CHAPMAN.
JOHN CHILES.
HERBERT COPEMAN.
ALFRED GLANVILLE COX.
HARRY WALLACE CUTBILL.
FREDERIC JOHN DAWSON.
EDWARD CHARLES DIOXY.
ARTHUR ELSEE, B.A.
AMBROSE EMERSON, JUN.
THOMAS FREDERICK ENNIS.
JOSEPH EDWARD FADELLE.
GEORGE JAMES FURNESS.
PERCY TILLSON GASK.

HERBERT CHARLES GOSTLING.
GEORGE WILLIAM GREEN.
FRANK GROVE.
WILLIAM HENRY HAMER.
HENRY HISCOX.
JOHN HERBERT HOPPS.
CHARLES EDWARD JONES.
GEORGE ONNO HOMFELD KLOPP.
WILLIAM GEORGE WOOLCOMBE LAKE.
CHARLES AUGUSTUS LA ROCHE.
WILLIAM TURNER MACLELLAN.
JAMES WADDELL MALCOLMSON, Wh. Sc.
WILLIAM WRIGHT MARRINER.
WILLIAM AKERMAN MILLER.
JOHN STOTT MILLINGTON.
THOMAS ARTHUR PEACE, B. Sc., Wh. Sc.
ERNEST PREBBLE.
HERBERT BYROM RANSOM.
BRIAN ALBERT RAVES.
GUSTAVE CHARLES REINHOLD.
WILLIAM HENRY REVILL.
CHARLES HAY RIVERS.
WILLIAM LLOYD ROACH.

Students, continued.

RICHARD HENRY ROE.
JOHN CHRISTOPHER ROME.
ERNEST EDWARD SAUNDERS.
JOSEPH RISLEY SETTLE.
PHILIP ALAN SHARMAN.
WILLIAM MACDONALD SHEPHERD.
ALEXANDER ARTHUR DALRYMPLE
SMITH.
WALTER STARBUCK.
DUNCAN HUBERT STEWART.

FREDERICK CHARLES JOSEPH STOWELL.
CHRISTOPHER WILLIAM TAYLOR.
JOHN BAIRD THOMPSON.
THOMAS HEATHCOTE TRAGETT.
JAMES DENIS TWINBERROW.
JOHN WULSTAN TWINBERROW.
HENRY HAGUE VAUGHAN.
CHARLES JAMES POWER WALLER.
FRANCIS ERNEST WENTWORTH-SHEILDS
JOSEPH HENRY WOOLCOCK.

The following Candidates were balloted for and duly elected as

Members.

EDWARD EVERETT BENEST.
JAMES MARLOW BURKE.
LEWIS METZLER CLEMENT.
GEORGE LESLIE COOK.
GEORGE SMITH DUNCAN.
CHARLES DE NEUVILLE FORMAN.
EDMUND PHILLIPS HANNAFORD.
ROBERT BATSON JOYNER.

JOHN LUNT.
ROBERT MOORE.
ROBERT HENRY RYAN.
WILLIAM SELLERS.
HENRY SIMON.
JOHN DOBSON WARDALE.
CHARLES EDWARD DELANCY WARING.

Associate Members.

FREDERICK WILLIAM BACH, Stud. Inst.
C.E.
FRANK OSBORNE BAIRD.
ROBERT SAMUEL WEMYSS BARNES.
HERBERT STANHOPE BASSETT, Stud.
Inst. C.E.
CHARLES JOSEPH BATLEY, Stud. Inst.
C.E.
JOHN JAMES BOURNE BENSON, Stud.
Inst. C.E.
ANDREW STEVENSON BIGGART.
THOMAS MOYLES BIGLEY.
JOHN FULLER BOAKE, Stud. Inst. C.E.
ANTONIO LUPICINIO BUARQUE.
ADAM HORSBURGH CAMPBELL, Stud.
Inst. C.E.
CHARLES ASHLEY CARUS-WILSON, B.A.
ALFRED JONES COLLIN.
ARTHUR ELLISTON COLLINS.
JOSÉ MARIA DA CONCEIÇÃO, Jun.
FRANK PLANT COOK, Stud. Inst. C.E.
FREDERICK WILLIAM CROSS, Stud. Inst.
C.E.
HARKER CHARLES CRUMMACK.

HARLEY HUGH DALRYMPLE-HAY, Stud.
Inst. C.E.
JOSEPH BASIL DENISON.
HERBERT HENRY GRAHAME DUNLOP,
Stud. Inst. C.E.
JAMES HENRY DUQUEMIN.
FREDERICK LAW DWYER, B.A.
SYDNEY CHARLES EARLY, Stud. Inst.
C.E.
JAMES COOK EASTHAM.
WALTER CLEEVE EDWARDS, Stud. Inst.
C.E.
REGINALD EATON ELLIS, Stud. Inst.
C.E.
EDGAR IVOR EVANS, Stud. Inst. C.E.
HENRY SIDNEY HOWARD FARRAR.
THOMAS WALKER FOWLER.
KENTATSU FUJIKURA.
RALPH STEPHEN GLOVER.
JOHN GOODMAN, Wh. Sc., Stud. Inst.
C.E.
WILLIAM HENRY MACKENZIE GREENE.
JOSEPH HARRISON, Wh. Sc.
HENRY ASHTON HILL.

Associate Members, continued.

ARTHUR JOSEPH JACK, Stud. Inst. C.E.	THEODORE REUNERT.
CHARLES CARKEET JAMES.	JOHN HENRY HORACE WENTWORTH RHODES.
PIROSHAW BOMANJEE JEEJEEBHOY.	RICHARD HUGO OSWALD BOEHRICHT.
HENRY ARTHUR JOHNSON, Stud. Inst. C.E.	JOHN CHRISTOPHER ROLLESTON.
JOHN MONTGOMERY JOHNSTON.	HERBERT RUMSEY.
JOHN EDWARD JONES.	WILLIAM SHARPEY SEATON.
WILLIAM GEORGE JONES.	ARCHIBALD SHARP, Wh. Sc., Stud. Inst. C.E.
JAMES PERCY KNIGHT, Stud. Inst. C.E.	PERCY JOHN SHELTON.
GEORGE LANE.	GEORGE THOMAS SIBBERING, Stud. Inst. C.E.
JAMES IBBS LAWSON, Stud. Inst. C.E.	ROBERT ALGERNON SUMNER.
EDOUARD ELIE LEFEBURE, Stud. Inst. C.E.	JOHN CHARLES TAITZ.
HENRY HARINGTON LEIGH.	HAROLD BLAKE TAYLOR, F.C.H., Stud. Inst. C.E.
DAVID MICHAEL LITSTER.	JOHN HUTTON THOMLINSON.
JOSEPH ERNEST MARTIN.	WILLIAM THWAITES, M.A.
WALTER RICHARDS MARTIN.	EDMUND SPENSER TIDDEMAN, Stud. Inst. C.E.
JAMES ARCHIBALD MAUGHAN.	CHARLES ALFRED TREBY.
WILLIAM OLIVER EVELYN MEADE-KING.	JOSIAS EDWARD DE VILLIERS.
OTAGAWA MASAYUKI.	ALFRED EDWARD WACKRILL, Stud. Inst. C.E.
ALFRED GEORGE NASH, B.Sc.	CHARLES PARRY WARDE, Stud. Inst. C.E.
TRENHAM OLD, Stud. Inst. C.E.	GEORGE WEBB WARE.
FREDERICK ORTON.	GEORGE KINDERSLEY WASEY.
WILLIAM OSMOND, Stud. Inst. C.E.	ROBERT WILLIAMS.
WILLIAM LAMBDEN OWEN.	JOHN ALEXANDER WILSON.
WALTER PARRY.	WALTER GUNNELL WOOD, Stud. Inst. C.E.
ANDREW LOUIS PAUL.	VINCENT SYDNEY WOODS.
THOMAS THEOPHILUS PRENTICE.	JOHN THOMAS WYNNE.
RICHARD PROVIS, Stud. Inst. C.E.	
THOMAS EDWARD QUIRK.	
EDWARD RADCLIFF.	
FREDERICK HOWELL REES.	
HENRY REEVE.	

Associates.

Colonel RICHARD HARRISON, C.B., C.M.G., R.E.	JOSEPH BOND MORGAN.
WILLIAM LEIGHTON JORDAN.	PHILIP ARTHUR SCRATCHLEY, M.A.

(Paper No. 2266.)

“Electrical Tramways: the Bessbrook and Newry Tramway.”

By EDWARD HOPKINSON, M.A., D.Sc., Assoc. M. INST. C.E.

ALTHOUGH the subject of the application of electricity to locomotion has been much discussed during the last few years, comparatively few attempts have been made at its practical realization. The first electrical tramway in the United Kingdom, constructed between Portrush and Bushmills, in the north of Ireland, was opened for traffic in October, 1883, and has since been extended. In his lecture before the Institution¹ in March, 1883, the late Sir William Siemens gave a general description of this line, and the electrical details were further discussed in a Paper read before the Society of Arts in April, 1883, by the Author.² In 1883 Mr. Magnus Volk constructed a line along the foreshore at Brighton, upon which a single car has since been running regularly, and Messrs. Siemens Brothers have a short length of line in operation on the pier at Ryde. On a larger scale is the tramway along the promenade at Blackpool, 2 miles in length, constructed by Mr. Holroyd Smith. The construction and method of working have been fully described by Mr. Smith, in a Paper read before the British Association at the Birmingham meeting, 1886.³ The conductor, as in the before-mentioned lines, is continuous, and several cars are in motion on the track at the same time. The cars are of various sizes, and accommodate from thirty to fifty-six persons. The track is nearly level, and a speed of 6 miles per hour is generally attained. Mr. Reckenzaun and Mr. Elieson have also done much in the application of storage batteries to tramway work.

In none of these instances has any attempt been made at the regular haulage of minerals and goods, nor at the operation of cars larger than the ordinary tramway type. Probably in no case has the effective power of any single motor exceeded about 4 HP. In July, 1884, Mr. Barcroft, of the Bessbrook Spinning Company, whose extensive flax-mills and stone-quarries are situated at Bessbrook, about 3 miles from Newry on Carlingford

¹ The Inst. C.E. Lectures on “The Practical Applications of Electricity.” Session 1882-83. “The Electrical Transmission and Storage of Power.” By Dr. C. William Siemens.

² Journal of the Society of Arts, vol. xxxi. p. 531.

³ See *The Electrician*, September 10, 1886.

Lough, suggested to the Author that the line, which the company had decided to make between Newry and Bessbrook for the carriage of coal and flax from the wharves to the mills and the down traffic of manufactured goods, might be worked electrically, for which the abundant water-power available offered exceptional advantages. The following conditions were to be met. Ten trains to be run in each direction per day, providing for a daily traffic each way of 100 tons of minerals and goods, and capable of dealing with 200 tons in any single day, in addition to the passenger traffic: the electrical locomotive to be capable of drawing a gross load of 18 tons on the up-journey, in addition to the tare of the car itself and its full complement of passengers, at an average speed of 6 miles per hour, and a load of 12 tons at an average speed of 9 miles per hour. The company agreed to place the line entirely at the disposal of the Author for a period of time, and to purchase the electrical plant at a fixed sum, when the above conditions had been complied with, and it had been shown that the cost of working, as evidenced by six months' trial, did not exceed the cost of steam traction on a similar line. The work was commenced in November, 1884, and the line opened for traffic in October, 1885, and was formally taken over by the company as having fulfilled the conditions of the contract in the following April. Since that time it has been in regular daily operation.

GENERAL DESCRIPTION OF THE LINE.

The line commences at the Edward Street Terminus of the Newry branch of the Great Northern Railway, and runs parallel to it for about $\frac{3}{4}$ mile, and then passing through a cutting follows the course of the Camlough stream, running under the central arch of the viaduct on the main Great Northern line, which crosses the valley at a height in the centre of 126 feet. Near the viaduct is the first station, close to the small village of Craigmore and an outlying mill of the Bessbrook Company. Proceeding up the valley with a gradient of 1 in 50, the county road is crossed diagonally by a level-crossing 50 yards in length, near which is the second station, Millvale, at which point the line crosses the stream and the turbine and generating dynamos are erected; the line again crosses the stream $\frac{3}{4}$ mile from Millvale, and thence runs into the terminus at Bessbrook, where a station and carriage shed are erected. The total length of the line is 3 miles 2·4 chains, and the average gradient 1 in 86, the maximum gradient being 1 in 50 (Fig. 1). The gauge is 3 feet, and the rails are at

FIG. 1.

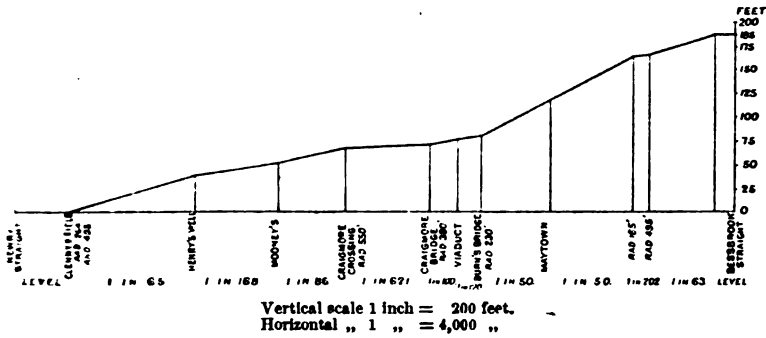
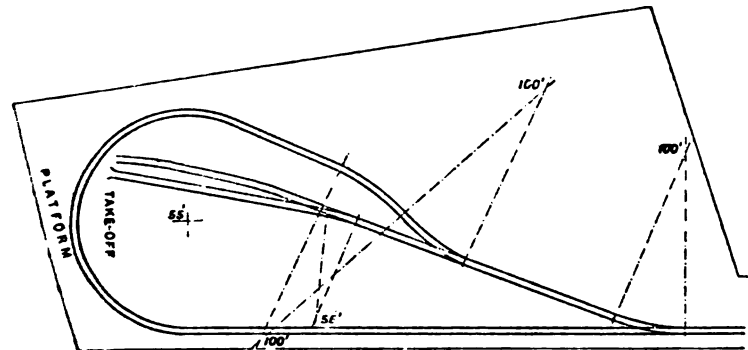


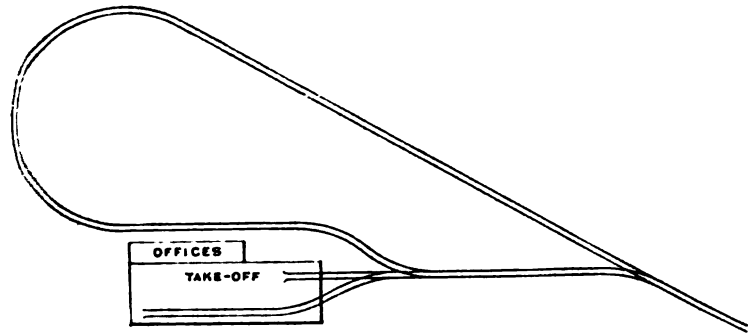
FIG. 2.



PLAN OF ARRANGEMENT OF LINES AT NEWRY.

Scale 1 inch = 100 feet.

FIG. 3.



PLAN OF ARRANGEMENT OF LINES AT BESSBROOK.

Scale 1 inch = 100 feet.

present single, but land has been acquired for a double line. At each terminus is a loop of 55-feet radius (Figs. 2 and 3), so that the cars do not need reversing, except in coupling up the wagons or shunting in the sidings. The permanent way has been laid out and constructed under the supervision of Mr. J. L. D. Meares.

LOCOMOTIVE EQUIPMENT.

The locomotive equipment of the line consists of two passenger cars, 33 feet and 21 feet 8 inches long respectively, each provided with a motor. The body of the car is carried on two four-wheeled bogies with a wheel-base 4 feet 6 inches, the motor being carried on the front bogie independent of the body of the car (Fig. 4). This arrangement enables the cars to traverse the 55-feet curves at the termini with great facility, and also relieves the body of the car from the vibration due to the driving. The body of the longer car is divided into three compartments, the front one covers the motor, the second forms a second-class compartment seating twenty-four passengers, and the third a first-class compartment seating ten passengers, separated from the second by a cross-passage. The front bogie carrying the motor has an extended platform, projecting 3 feet 7 inches beyond the body of the car, and communicating by a slide-door with the dynamo-compartment, thus giving the driver direct access to all parts of the driving machinery, which are at the same time entirely boxed off from the passenger compartments. All four wheels are braked by a powerful screw-brake worked from the front of the driving-platform, on which is also fixed the switch-board controlling the motor. The wheels of the back bogie are braked by a chain-brake worked from the cross-passage and are under the control of the conductor. This brake is also prepared for coupling to the wagons. The total weight of the car is $8\frac{1}{2}$ tons, distributed as follows:—

	Tons.	cwt.	qrs.
Car-body	3	6	1
Leading bogie	1	17	2
Trailing „	1	0	0
Dynamo, bed-plate, armature, and accessories	2	1	1
	8	5	0

The shorter locomotive-car is similar, but without the first-class compartment. Both cars were built by the Ashbury Carriage Company, of Manchester. There is also a third passenger-car of the same length as the first, and accommodating forty-four pas-

FIG. 4.

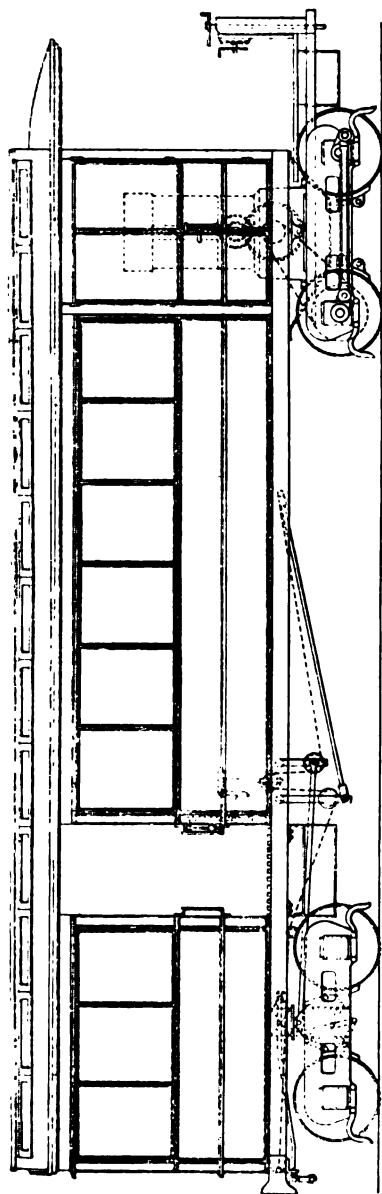
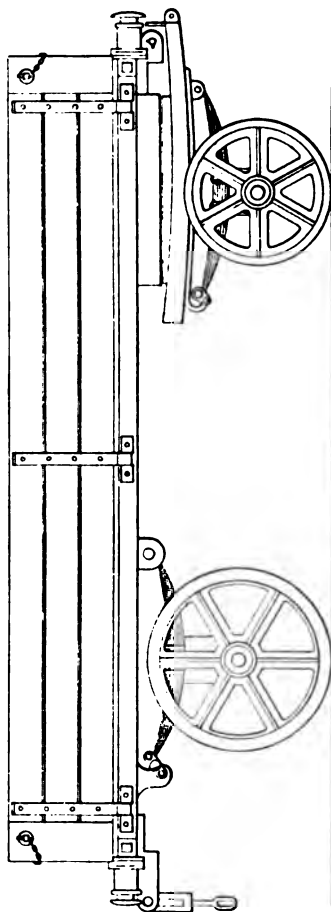


FIG. 5.

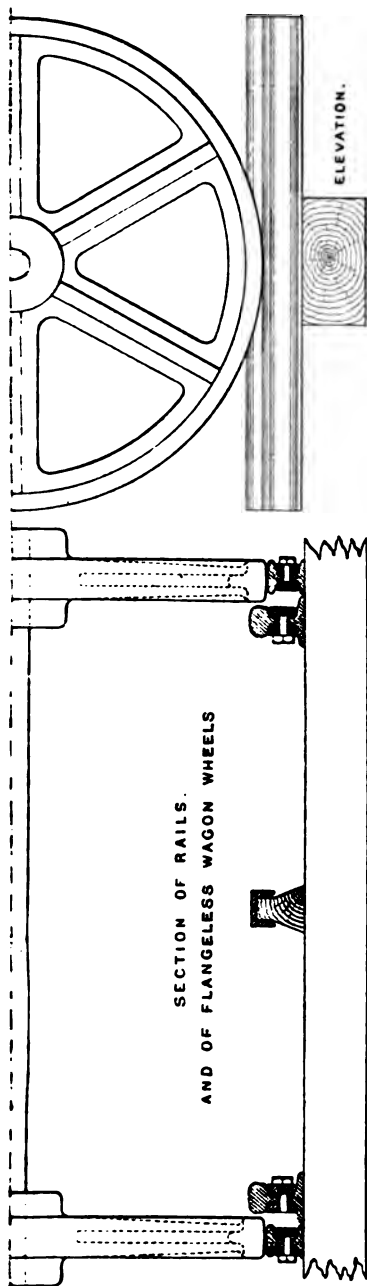


sengers, and similarly carried on two four-wheeled bogies. This car weighs $5\frac{1}{2}$ tons, and was constructed by the Starbuck Company, of Birkenhead.

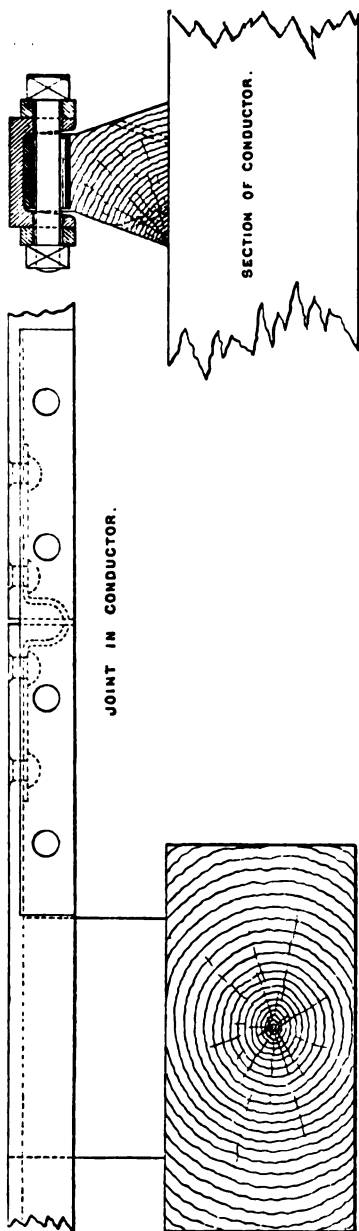
THE USE OF WAGONS WITH FLANGELESS WHEELS.

Apart from the electrical working of the line, an important and novel feature is the plan by which the wagons used on the line can also be used on the ordinary public roads, so avoiding the necessity of transshipment, and enabling goods to be loaded at the wharves, and drawn to the line by horse-power, and again delivered at any part of the mill premises. The plan was originally suggested in 1880, by Mr. Alfred Holt, M. Inst. C.E., of Liverpool, and was embodied in the Lancashire Plateways Scheme, for which a Bill was lodged in the autumn of 1882, and subsequently withdrawn. The idea has been worked out in a practical form with great success by Mr. Henry Barcroft, of Newry, one of the directors of the company. The wheels of the wagons are constructed without flanges, with tires $2\frac{3}{4}$ inches wide, which is sufficient for use on ordinary roads (Fig. 5). Outside the tramway rails, which are of steel, and 41·25 lbs. per yard section, second rails are laid, having a section of 23·75 lbs. per yard, with the head $\frac{7}{8}$ inch below the head of the larger rails. The flangeless wheels run upon these lower rails, the ordinary rails forming the inside guard (Figs. 6). The wheels are loose on the axles; but the latter are not fixed, but are carried in journals, so that there is freedom in both wheel and axle, which considerably reduces the friction, especially in travelling round curves. The front part of the wagon is supported on a fore-carriage, which can either be pinned or allowed freedom of motion, as in an ordinary road vehicle (Fig. 4). The buffers are fixed on the truck-frame, and no buffing is done against the fore-carriage. There is a single central coupling arranged to engage in a jaw in the fore-carriage, so as to guide it when not pinned. Shafts are attached to the fore-carriage when the wagon is to be used on the ordinary roads. The weight of each wagon without the shafts is $23\frac{1}{4}$ cwt., and the wagons are of sufficient strength to carry a load of 2 tons. This load is not too much for a single horse on roadways where there are no steep gradients; on steep gradients two horses are required. The double line of rails is not continued round the curves at the termini, but a take-off is arranged (Figs. 2 and 3) into which the wagons are run by the car. The shafts are then affixed, and the wagons drawn off by horses. Twenty-two of these wagons have been supplied

FIGS. 6.



FIGS. 7.



to the Tramway Company by the Ashbury Carriage Company, and have been in constant use for eighteen months. Experience has shown that the wear and tear, both on the wheels and rails, is not excessive, and that the traction does not much exceed, if at all, that of ordinary trucks with flanged wheels. No difficulty has been found with the horse traction on ordinary roads, and the taking on and off is conducted with great rapidity. The utility and wide applicability of this plan are obvious, and it may do much to develop the introduction of short tramways where the cost of transshipment would be fatal to the ordinary methods of working.

HYDRAULIC AUTOMATIC GATE-OPENER.

Another novel device introduced by Mr. Barcroft is an automatic hydraulic apparatus for opening the gates protecting the level crossing of the county road. The regulations of the Board of Trade require that gates should be provided at such crossings, and that they should be closed immediately after the passage of the train. To avoid the cost of a gateman, the following plan has been adopted. As the locomotive car approaches the crossing at a distance of about 50 yards, a suitable arm attached to the foot-board strikes a lever pivoted on one side of the permanent way, and turns it over. The lever is connected with a three-way cock, which, when opened, withdraws the water from a cylinder provided with a float. To this float a wire rope is attached, which opens the gates on both sides of the crossing as the float sinks in the cylinder. After passing the crossing, the car strikes a second lever similarly situated and connected by a second wire rope to the three-way cock. When the lever is thrown over, the cock is turned so as to admit water from a cistern placed at a higher level into the cylinder, raising the float and closing the gates, the float being assisted by a balance-weight attached to each gate.

GENERATOR STATION.

The generating machinery is fixed at Millvale, a distance of 68 chains from the Bessbrook terminus. At this point, in close proximity to the line, there is an available fall of 28 feet in the Camlough stream, down which there is a guaranteed minimum flow of 3,000,000 gallons per day. The turbine is an inward-flow vortex wheel with double buckets, working on a horizontal shaft extended into the dynamo shed, from which the dynamos are driven direct with belts. The capacity of the wheel is 1,504 cubic

feet per minute, and when running at 290 revolutions per minute should develop a maximum power of 62 HP. It is worked with a tail draught of 13 feet. The admission of water is controlled by a shutter-valve regulating the flow uniformly through each bucket of the wheel, and actuated either by hand or by a centrifugal governor. The latter is not direct acting, but as its balls rise or fall beyond certain limits, couples one of a pair of right- and left-hand bevel-wheels driven by a wheel on the governor-spindle to a small countershaft, geared with the valve-spindle.

There are two generating dynamos of the Edison-Hopkinson type, manufactured by Messrs. Mather and Platt, of Manchester. Each is shunt-wound, and intended for a normal output of 250 volts, 72 amperes, at a speed of 1,000 revolutions per minute; but they are never used coupled, as one dynamo is found to be sufficient for the working of the line. Although the average current for a day's work does not exceed 72 amperes, the current required for starting a heavy train on a steep gradient may be three times this amount. It is essential, therefore, that a dynamo intended for such purposes should not only be mechanically strong enough to develop an output far exceeding its normal output, but also that its design should be such that the variation in the lead of the brushes with the current should be as small as possible, and that the fall in electromotive force as the current increases should not be excessive. The latter condition can be met by compound winding, but on the other hand the ease with which shunt machines can be coupled parallel is in favour of their use. It is also of considerable importance to keep the self-induction of the main circuit as a whole as low as possible, otherwise the sudden variations in current at stopping or starting of the train is a severe strain on the insulation both of the generator and motor dynamos and on the conductor cables. If the generator dynamo were series-wound, or partially so, the self-induction of the circuit would be considerably greater than with a simple shunt-wound generator. Both by reason of the small variation in lead and electromotive force, and also the mechanical strength of the drum form of armature, the dynamos employed are particularly well suited for the purpose, and have given most satisfactory results. The resistance of the field-magnets is 74 ohms, and of the armature 0.12 ohm; consequently the electrical efficiency, when working with the normal current, is 92.2 per cent., and the commercial efficiency 90.4 per cent.

CONDUCTOR.

The conductor (Figs. 7, p. 199) is of channel-steel, laid midway between the rails, and carried on wooden insulators nailed to alternate sleepers. The channel form presents several obvious advantages. It can be obtained readily in a variety of stock sections without being specially rolled for the purpose. It does not require to be secured, but can be simply laid on the insulators which fit into the channel, and while allowing longitudinal motion to compensate for changes of temperature, hold it laterally. It is also a most convenient section for making the joints between consecutive lengths. The joint must be sufficiently strong mechanically and at the same time offer no electrical resistance. Double fish-plates placed externally on either side the webs are sufficient for the first object, but the rust between the surfaces in contact often causes almost complete insulation. The electrical connection is therefore made independently by a strip of soft copper of such section that its conductivity is about the same as the steel. It is bent in a U form to allow for the expansion and contraction of the channel. These strips are riveted in the channel with double copper rivets, care having been taken that the hole in the channel was perfectly free from rust before the riveting. At the several crossings of occupation roads, twelve in number, the electrical continuity of the conductor is broken by insulating a section of the channel, and the current is conveyed by a cable laid beneath the sleepers. The top of the channel being level with the rails, the intervening space can be paved or planked, thus making a good roadway without interfering with the mechanical continuity of the conductor. As none of these crossings exceed in width the length of the locomotive cars, the leading collector makes contact on one side the crossing before the back collector breaks on the other. The cables are of stranded copper wire, consisting of thirty-seven No. 14 B. W. G.—1st, cotton lapped and varnished; 2nd, heavily covered with pure rubber; 3rd and 4th, double served with best rubber separator; 5th, covered with pure rubber; 6th and 7th, taped with double-served proof tape, the cable then vulcanized and made water-tight; 8th, lapped with thick serving of tarred hemp; 9th, braided overall and heavily compounded.

In constructing a conductor of iron or steel, it is of the utmost importance to specify the composition. Steel may be obtained with a specific resistance, varying from 0.00001 ohm to 0.00007 ohm, according to the amount of carbon, silicon, and particularly

manganese.¹ The steel used was manufactured by the Darlington Steel and Iron Company, and specified not to exceed in carbon 0·15 per cent.; silicon, 0·05 per cent.; manganese, 1·00 per cent. The actual composition according to the makers' analysis is: carbon, 0·09 per cent.; silicon, 0·02 per cent.; manganese, 0·63 per cent.; and the specific resistance 0·0000121 ohm. The weight per foot of the conductor is 4·33 lbs. (6·46 kilograms per metre), and the section 1·367 square inch (8·817 square centimetres). The cost, delivered at the wharf at Newry, was £7 10s. per ton. High conductivity copper could not at that time be bought under £84 per ton, with a specific resistance of 0·0000016 ohm, showing a gain in favour of steel over copper, having regard to weight and conductivity, in the ratio of 3 to 2.

At one point the line crosses a country road obliquely, the crossing being 150 feet in length. The method before described of bridging the gap was here not feasible, and it was necessary to resort to some other device. A copper wire was slung centrally between the rails from cross-bars carried on posts, placed on each side the rails at either end of the crossing, the lowest part of the catenary being 15 feet above the road-level, to meet the requirements of the Board of Trade. An overhead collector, formed of bar-iron, fixed above the roof of the car, passes under the cross-bar, and immediately makes contact with the wire before the back collector leaves the ground conductor, and continues to make a rubbing contact until the leading collector has again made contact with the ground conductor on the other side the crossing. This method of carrying the conductor and making contact with it was devised in 1885 by the Author's brother, Dr. John Hopkinson, and has proved in every way a most complete success. The collector on the roof of the car, though merely a bar of flat-iron 1 inch wide greased with tallow once a week, makes a perfect contact with the copper wire sufficiently good for transmitting 120 amperes. After an experience of two years there is no perceptible wear on the wire except at the point where it is picked up by the collector, and even here it is very small. An overhead conductor has many advantages over one placed on the ground level or beneath. There is no interference with crossings; it is less subject to malicious or accidental injury; and particularly, perfect insulation and isolation can be secured, enabling currents

¹ "Magnetization of Iron." By John Hopkinson, Phil. Trans. 1885, vol. 176, p. 463.

of much higher potential to be used with safety. There is no doubt that some animals cannot stand a shock of 300 volts, and it is probable that the Board of Trade would not sanction the use of any higher potential, if there was a possibility of the conductor being accidentally touched. With an overhead conductor there is no such risk, and much higher potentials would be permissible, giving greater economy in the transmission of the power. On the other hand, the difficulty of making contact with an overhead conductor has hitherto opposed almost insuperable difficulties, now obviated by this simple device. In the crossing above referred to, two catenaries are used with the points of support at different levels, in order to reduce the tension of the wire and the pull on the posts, which in this instance is not balanced by a like pull on the opposite side, as would be the case were the conductor constructed throughout on this principle. The wires are of hard drawn copper, No. 4 B. W. G., and the actual tension is 120 lbs. The inclination of the catenaries to the horizontal is $\tan^{-1} \frac{3}{38}$, and the collector clears the underside of the cross-bar by $5\frac{1}{2}$ inches, and therefore picks up the conductor at a distance of 64 inches from the posts.

The insulators upon which the channel-steel is supported are blocks of poplar wood, 5 inches long. These are carefully dried, and then impregnated with boiling paraffin. A block of dried poplar will absorb as much as 75 per cent. of its own weight of paraffin, which permeates through the whole mass. These blocks have proved efficient insulators, and are apparently standing well. The actual measured insulation of the conductor, under unfavourable circumstances as regards weather and when charged to a potential of 250 volts, is about 900 to 1,000 ohms per mile, approximately the same as the Author obtained at Portrush.¹ Such an insulation is sufficient for practical purposes. It represents a loss through leakage of $\frac{1}{4}$ ampere or one-tenth of a horse-power per mile. The actual measured leakage current of the whole line in wet weather amounts to nearly four times the above amount, the excess being probably due to some slight fault in the cables and arrangements at the points and crossings.

The circuit is completed by the rails of the permanent-way, which are uninsulated. As is the case with the conductor, the fishplate connections are not sufficient, and are supplemented

¹ Mr. Holroyd Smith, with an underground conductor, found the leakage current to vary from 30 to 100 amperes, with an electromotive force of 220 volts, showing an insulation resistance of 4.4 to 13.2 ohms per mile.

by flexible copper strips riveted to the under surface of the rails. The specific resistance of the steel rails (Barrow Hematite) is 0·0000166 ohm, and hence the total resistance of the four rails, having an aggregate area of 12·4 square inches, is 0·033 ohm per mile. The resistance of the conductor is 0·221, making the resistance of the circuit 0·254 ohm per mile. Allowing for the earth and for some contact resistance, probably 0·25 ohm per mile fairly represents the average resistance (0·156 ohm per kilometre). The electrical connection of the rails of the permanent-way is essential, since the earth connection is of little value, as the rails are practically insulated by the sleepers and dry ballast. A curious confirmation of this occurred during a severe thunderstorm. At the first flash a man employed at the Newry end of the line, who was touching the rails but not the conductor and standing on wet ground, received a smart shock, and simultaneously with the lightning flash the attendant observed a blaze of light from the earth-brush of the generating dynamo. At the second flash a similar discharge was observed at the brushes, and at the third flash, more intense than the others, the same occurred again, and the fusible plug connecting the conductor with the dynamos gave way, and two men engaged at the Bessbrook end of the line and touching the rails but not the conductor received severe shocks. Clearly in each case the system as a whole had been struck, and the charge was making the best of its way to the earth. After this occurrence the precaution was taken of connecting the rails of the permanent-way to the earth at several points.

MOTORS.

Each locomotive-car is fitted with an Edison-Hopkinson dynamo-motor. As previously mentioned, the motor is fixed on the leading bogie, and is entirely independent of the body of the car. The armature shaft carries a double helical toothed steel pinion, 6·05 inches in diameter, gearing into a steel wheel 21·08 inches diameter, carried on a small counter-shaft running in bearings fixed on the bed of the motor. This shaft also carries a chain pinion-wheel of steel, 8·8 inches diameter, on the extended boss of which the helical toothed wheel is keyed. The chain-pinion drives with chain-gear on to a wheel 21 inches in diameter, keyed on to the back axle of the bogie, the wheels of which are 28 inches in diameter. This gives a ratio of gear of 8·3 to 1; hence a speed of 1 mile per hour corresponds to 100 revolutions

per minute of the dynamo axle. To give the necessary adhesion, the axles are coupled with outside connecting-rods.

The motors are series-wound with such a number of convolutions that the magnets are nearly saturated with 72 amperes, which is also the normal current for the armature. The resistance of the magnets is 0·113 ohm, and of the armature, 0·112 ohm; hence, if the potential between the terminals be 220 volts, the electrical efficiency with the normal current is 92·6 per cent., and the commercial efficiency 90·7 per cent., the power developed being nearly 20 HP. In actual work the power of the motor frequently exceeds this amount. To transmit this power with the car running at, say 7 miles per hour, the tension of the chain would be 1,430 lbs., and the speed 460 feet per minute. At starting on a gradient with the full load, the tension may reach 3,400 lbs., and with the car running at the maximum rate, the speed may reach 1,300 feet per minute. Considerable difficulty was experienced in obtaining a chain strong enough to stand the high working tension, and at the same time not unduly heavy for running at the high speed. Several chains of the well-known tricycle form were tried. In these the inside link is fitted with two tubes, through which the pins of the outside link pass, so as to give a wearing surface across the full width of the chain. The tube is protected by a loose roller, intended also to reduce the friction. It was found, however, that the impact of the chain against the teeth of the wheel flattened out the rollers, and ultimately split them; also, sooner or later the tube became loose in the inside links, and began to wear. A steel chain, specially constructed by Mr. Hans Renold, was finally tried, in which the tubes were keyed as well as riveted in the inner links, and the pins in the outer, and the rollers abandoned (Figs. 8). The average breaking-stress of the steel is $43\frac{1}{2}$ tons per square inch.

Pitch of chain	= 2·125 inches.
Weight	= 8·5 lbs. per linear foot.
Strength of pins against shear =	13·8 tons.
" outside links	= 10·2 "
" inside "	= 14·8 "

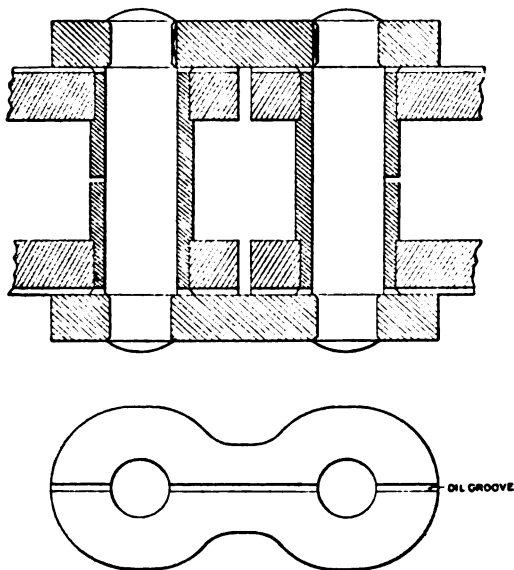
The wearing surface per foot of chain is 16 square inches, whereas in the ordinary bowl or stud chain of the same strength the wearing surface would not exceed 2·5 square inches. One of these chains has been at work over eighteen months without showing signs of wear or stretching.

The current is conveyed from the conductor by two collectors fixed on the bogies. These form a good rubbing contact on the

upper surface of the conductor. From them the current passes to the reversing and regulating switch fixed on the splash-board of the leading bogie. To avoid throwing the full load suddenly on the generator and motor dynamos, a series of resistances are first thrown into circuit and cut out one by one. After passing through the armature and magnets the current returns through the axle-boxes and wheels to the rails.

The potential allowed by the Board of Trade is 300 volts, but the actual potential employed is 250 volts only.

FIGS. 8.



STEEL CHAIN FOR LOCOMOTIVE TRAMCAR.

† full size.

The trains are commonly composed of one locomotive-car and three or four trucks, but frequently a second passenger-car is coupled, or the number of trucks increased to six. Thus a gross load of 30 tons is constantly drawn at a speed of 6 or 7 miles per hour, on a gradient of 1 in 50.

EFFICIENCY EXPERIMENTS.

In order to test the efficiency of all the component parts under various conditions of load, several series of observations were

made as the car travelled from Newry to Bessbrook with six, four, and no trucks respectively. The flow of water, the potential of the conductor, and the speed of the car were ascertained at frequent intervals, and the results plotted in the form of curves, with the time as abscissa. From these observations and the known resistances of the generator, motor, and conductor, the loss in the several portions of the system, and the actual power developed by the motor, can be readily calculated, and the results similarly shown in a graphic form. The points representing actual observations are joined by straight lines, though no doubt a line of continuous curvature would more accurately represent the fact; but the method employed has the advantage of distinguishing at a glance observation from interpolation.

The curves, Plate 1, Fig. 1, give the results for a journey with a gross load of 28 tons 12 cwt. 3 qrs., including the locomotive car.

The curves, Fig. 2, for a gross load of 21 tons 18 cwt.

The curves, Fig. 3, for a gross load of 8 tons 16 cwt.

Hitherto, writers on electrical locomotion have considered the question of mechanical efficiency from individual observations made at a given instant, when the conditions might or might not be favourable. By a suitable choice of conditions it is very easy to deduce extraordinary high figures of efficiency for electrical working; but such figures are misleading, and not a fair basis of comparison with other modes of locomotion. Since the conditions are constantly varying between very wide limits, any calculation of efficiency ought to take account of the average conditions, or, in other words, the results of a series of individual observations taken at intervals ought to be integrated in respect of time. The curves enable this to be readily done by determining the areas bounded by them and the axis of abscissas. The results are given for the three series of curves in Tables I, II, and III in the Appendix.

Table IV in the Appendix also gives the results of the integration for the three journeys, showing the work done by the water, the electrical energy developed by the generator, the loss in leakage, resistance of line, magnets and armature of generator and motor respectively, and the mechanical work done by the motor, all expressed in foot-lbs. Table V gives the results in Table IV tabulated as percentages of the total energy of the water, and also of the electrical work done by the generator. It will be observed that the efficiency of the whole combination varies from 26·1 per cent. for the light load to 41·3 per cent. for the heavy load; whereas the efficiency of the electrical portion varies from 69·4 per cent. for the heavy load to 76·8 per cent. for the light load. This is

explained entirely by the very low efficiency of the turbine when running with a light load. When loaded to nearly its maximum capacity its efficiency is 60 per cent., which is not unfavourable, considering that the load is constantly varying, and that the friction of the shaft, belts, and dynamos, as also the power required to drive the governor, are included. Considering the problem as an electrical one only, it appears that the efficiency does not vary greatly with the load, falling only from 76·8 per cent. to 69·4 per cent., as the load is more than trebled. Taking the average of the three journeys:—

Electrical efficiency	= 72·7 per cent.
„ loss in generator	= 8·6 „
„ „ leakage	= 5·7 „
„ „ line resistance	= 6·6 „
„ „ motor	= 7·7 „ ¹

The loss as given above in the generator and motor does not include the friction of the bearings nor the power required to turn the armature in the excited fields, when no current is passing through it, both of which, however, are very small.

Comparing the proportion of the total energy of the water, which can be applied to traction in the electrical locomotive, with the proportion of the total energy of coal, which can be usefully applied in a steam-locomotive, the former has been seen to be over 40 per cent. Mr. G. C. Cuninghame, M. Inst. C.E., estimates the latter from experiments tried on the Canada Southern Railway at 3·5 per cent.²

Referring again to Table IV, if the work done against gravity be subtracted from the total work done by the motor, the remainder represents the work done against all the frictional resistances. From this and from the distance traversed the mean tractive force can be at once deduced. The results for the three journeys are respectively 28·9, 27·4, and 37·1 lbs. per ton of gross load hauled. The two former agree well. The increase in the third is due to two causes, first, the mean speed is nearly double that in the first journey, the effect of which on the mean tractive force would be increased by the frequent and sharp curves of the line; secondly, the locomotive car having no trucks attached to it on the third

¹ It will be observed in the tables that the totals given do not always correspond exactly with the sums of the components. This arises from the curves being separately integrated. The error of about 1 per cent. is a measure of the accuracy of the method.

² Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 325.

journey, the friction of the driving-gear, connecting-rods, &c., would bear a much larger proportion to the whole. The values given above for the tractive force include the friction of the chain and driving-gear, as also that of the motor dynamo in its bearings, and the couple required to turn the armature with the fields excited but no current passing through it. It corresponds in a steam-locomotive to the product of the mean pressure on the piston and the ratio of the throw of the crank to the radius of the driving-wheel.

The foregoing results also afford some examples illustrative of the general theory of a series-wound motor. In such a motor let L be the couple on the armature shaft; R the resistance of the series coils and armature; r the additional resistance inserted; C the current; P the potential of the conductor; E the electromotive force of the motor; and ω the angular velocity of the armature. Then

$$L \omega = E C$$

$$\text{And } E = P - R + r C.$$

$L\omega$ here includes the power lost in the armature of the dynamo through the reversal of its magnetization, the power lost through the short-circuiting of successive coils at the commutator and local currents in the core, also friction of the bearings, in addition to the useful work done by the motor, as measured by a brake. The first of these losses, which is or ought to be the most important, is proportional to the velocity ω , and the latter with sufficient accuracy for the present purpose may be assumed to be so. ($L + l$) may therefore be written for L , where L represents the couple doing useful work external to the dynamo. Let $E = \frac{\omega}{\Omega} f(C)$ be the characteristic curve of the dynamo, then

$$L + l = \frac{C f(C)}{\Omega}.$$

C is therefore independent of the velocity, and depends upon the couples only. It must be remembered that C being measured in amperes, L and l are measured in the corresponding C. G. S. unit of work denominated by the late Sir William Siemens a "Joule." (One Joule = 10^7 ergs = 0.74 foot-lb.) Since within very wide limits $f(C)$ increases as C increases, $L + l$ increases as C increases. In this lies the chief advantage of a series-wound dynamo for locomotive purposes. The maximum couple which a steam-locomotive can exert is limited by the steam-pressure and the area

and stroke of the piston. In a water-wheel the couple cannot exceed the product of the radius of the wheel and the maximum weight of water its buckets can contain. So in a turbine. In a series-wound dynamo there is no limit to the couple it can momentarily exert, except the mechanical strength of the armature, provided the potential of the conductor does not fall below $R + r C$. It may be said that the current is limited by the couple turning the generating dynamo. This no doubt is true, but in many cases the generating dynamo is sufficient for working several motors, and the motor which at the instant requires to exert the greatest pull can draw the full current of the generator; and in every case there is the momentum of the generating dynamo and of the engine or other prime motor driving it, which must be exhausted before the amount of current is limited. In the present instance the motors on the cars are designed for working continuously with a current of 72 amperes, with which current the couple the dynamo exerts is 183 Joules, or 135 foot-lbs., which is increased to 1,120 foot-lbs. on the axle, equivalent to a tractive force of 960 lbs. The observed current required to start a train of 29 tons on an incline of 1 in 50 was 170 amperes (Plate 1, Fig. 1), corresponding to a tractive force of 2,544 lbs., equal to 88 lbs. per ton, or about three times the normal tractive force exerted by the motor. For a line such as the one under discussion a simple shunt-wound motor would be useless, since at the moment of starting on a steep incline the potential of the conductor at the motor may be reduced to one half its normal amount through the resistance in circuit, and consequently the magnetizing force reduced in like proportion, when the fields would almost entirely lose their magnetism. A compound-wound machine might be used, and would have the advantage that the speed would not exceed a certain limit, however small the load might be, but in the present instance such a provision was unnecessary. A further advantage in the use of a series-wound machine is the facility with which a motor of the Edison-Hopkinson type when wound in this manner can be reversed. In general, to reverse the direction of rotation of a motor the lead of the brushes must be reversed at the same time as the current through the armature, or there will be destructive sparking at the commutator. But if the lead can be reduced to such an extent that the brushes may be fixed at the neutral point without causing injurious sparking, it is only necessary to reverse the current. It is known that the angle of lead depends upon the disturbance of the magnetic field in the gap between the pole-pieces, due to the current round the armature, but no

successful attempt has yet been made to express the variation of the angle of lead in terms of the geometrical constants of the machine and the magnetizing forces. The disturbance of the field can, however, be minimised by maintaining the magnetizing forces in the field magnets very large compared with those in the armature, as is the case in a series-wound machine. In the present instance it has been found unnecessary to make any provision for the change of lead and the reversal of rotation is effected by reversing the current only.

Referring to curves, Plate 1, Fig. 1, it is seen that on an incline of 1 in 621 the locomotive car, when drawing a gross load of 28·6 tons, absorbed a current of 60 amperes, and that the electromotive force of the motor was 222 volts. From these measured results the couple exerted by the motor and the speed can be readily determined by aid of the characteristic curve. With a current of 60 amperes through the magnet coils, the electromotive force of the motor is 260 volts at a speed of 1,000 revolutions per minute, and therefore with 222 volts the speed will be 854 revolutions per minute, corresponding to a speed of travel of 8·57 miles per hour as against 8·4 miles measured. Again the couple exerted by the motor will be

$$\frac{222 \times 60 \times 60}{854 \times 2 \pi} \text{ Joules} = 149 \text{ Joules} = 110 \text{ foot-lbs.}$$

This is equivalent to 913 foot-lbs. on the axle of the car, or a tractive force of 785 lbs., i.e. 27·4 lbs. per ton. From this must be deducted 3·4 lbs. per ton for gravity, leaving 24 lbs. per ton, as against 28·9 lbs., the tractive force calculated from the mean of the work done over the complete journey. In the latter the force required to overcome the resistance of the curves, which are both numerous and sharp, is included, whereas the former figure applies to a straight portion of the line. This is probably sufficient to account for the difference between the figures. The example shows how precisely the results obtainable from an electro-motor when used for locomotion can be calculated.

USE OF STORAGE BATTERIES.

It is interesting to consider how far the system of storage batteries would be applicable to a line where heavy traffic has to be accommodated. In the first journey, with a load of 28·6 tons, the total work done by the motor was 12·6 HP. hours, and the loss

in the motor was 2·07 HP. hours, hence the total electrical energy absorbed by the motor was 14·67 HP. hours in thirty-six minutes or at the rate of 24·4 HP. According to results published by Mr. Reckenzaun in a communication to the American National Electric Light Association, a cell suitable for tramcar work, weighing 41 lbs., has a useful capacity of 137 to 156 ampere-hours, according as the rate of discharge is varied from 46 to 22 amperes; the electromotive force falling during discharge from 2·1 volts to 1·87 volt. Hence 1 ton of storage cells can do work usefully at the average rate of 3,700 watts, or 4·9 HP. From these data the weight of battery required to do the work actually accomplished at Bessbrook can be readily deduced. Remembering that the battery itself has to be carried, and making no allowance for increased weight in the framework of the car, the weight of battery required is 6 tons. But this additional weight would necessitate a considerably larger locomotive-car with a stronger frame and more powerful motor, which would again increase the weight of the train and the weight of the cells required. If the former be taken at 4·4 tons, the latter would be about 1 ton; hence the gross weight of the train would be increased to 40 tons, including the battery, weighing 7 tons. Assuming the efficiency of the battery to be 70 per cent., which is probably a favourable assumption, when the rate of discharge is variable, the electrical energy required to charge the battery for one journey would be 29·3 HP.-hours as against 16·4 HP.-hours required for the same work on the continuous conductor principle. Thus from the point of view of economy of power the comparison is greatly in favour of the continuous-conductor. There are the further considerations of first cost and depreciation of plant. To provide for the continuous working of the line two sets of accumulators would be required, which, taken at the present price of £60 per ton, would cost £840, to which must be added the cost of the larger locomotive-cars and more powerful motors. This would increase the cost to at least £1,200. Now the cost of the conductor, which is the only part replaced by the battery, was £600 (see Appendix). Again, the depreciation of the cells cannot be estimated at less than 40 per cent. per annum, whereas the conductor practically suffers no depreciation.

COMPARISON WITH WIRE-ROPE TRACTION.

Traction by a continuously moving wire-rope has many points in common with an electrical system on the continuous-conductor principle, and the efficiency of the two methods can be readily

compared. In a comprehensive review of the working of the cable tramways in San Francisco, Mr. Hanscom¹ gives the following results obtained from careful measurements on seven different lines:—

Total indicated power of engines	798·7 HP.
Total power absorbed in moving the cables .	548·2 „
" " " cars and passengers.	250·5 „

Hence on the average 32 per cent. of the total indicated power is available for moving the cars and passengers. Now in comparing this with the results obtained on the Bessbrook line, it must be remembered that a portion only of the net power developed by the motor is available for moving the cars, part being required for moving the motor and its carriage. About 3·5 tons of the total of 28·6 tons represents the dead-weight, and hence about 88 per cent. only of the net power is available for moving the effective load. Again, if for water-power steam-power were substituted, about 15 per cent. of the indicated power would be available for driving the generator dynamo. Hence the ratio of the power available for moving effective load to the total indicated power would be 54 per cent. as against 32 per cent. on the cable system.

In instituting the above comparison, both systems may be considered to be working under conditions calculated to favourably develop the characteristic features of each. The grades on the San Francisco lines are in cases as steep as 1 in 6, and 1 in 10 is not uncommon. On such lines any system of electrical propulsion, except perhaps by a geared locomotive, would be entirely inapplicable. On the other hand, the wire-rope system would present less favourable comparative results, if applied to a line similar to the Bessbrook line, where the gradients are less severe.

The Paper is accompanied by a series of drawings, from which Plate 1 and the Figs. in the text have been prepared.

¹ "Cable Railway Propulsion," by W. W. Hanscom. Transactions of the Technical Society of the Pacific Coast, 1884. Vol. i. p. 63.

APPENDIX.

COST OF CONSTRUCTION.

The cost of the electrical equipment of the line may be briefly summarized as follows:—

Turbine, pentrough, and driving-gear	£.	s.	d.
Two generator dynamos, measuring instruments, and driving-belts	330	0	0
Conductor, at £200 per mile	450	0	0
Two locomotive cars, including their entire electrical equipment	600	0	0
	1,120	0	0
	<u>2,500</u>	<u>0</u>	<u>0</u>

Each of the above items including delivery and erection.

COST OF WORKING.

The cost of haulage was carefully ascertained over a period of five months from November 21st, 1885, to April 22nd, 1886.

Wages of driver and attendant at generator station	£.	s.	d.
Sundry repairs	32	7	6
Oil, grease, and waste	6	1	0
Rental of water-power	5	4	10
Dynamo brushes, renewals of driving-chain, and commutators	59	16	0
	14	11	6
	<u>118</u>	<u>0</u>	<u>10</u>

Train-mileage = 8,652.

Hence cost per train-mile = 3·3d.

For the six months ending June 30th, 1887, during which period there had been a goods traffic of 8,000 tons over the line, a much larger amount than in the period referred to above, the cost per train-mile was somewhat greater, as follows:—

Wages	£.	s.	d.
Sundry repairs and alterations, including the cost of changing the winding of four armatures of the dynamos	50	18	0
Oil, grease, and waste	34	14	3
Rental of water-power	10	0	0
Dynamo brushes and sundry renewals	71	15	0
	12	5	10
	<u>179</u>	<u>13</u>	<u>1</u>

Train-mileage, 10,176.

Hence cost per train-mile, 4·2d.

The above figures do not include anything for depreciation or for general supervision.

TABLE I.—RESULTS OF INTEGRATION OF CURVES, Plate 1, Fig. 1.

Total water-power	30·4 HP. hours.
„ electrical-power developed by generator	18·1 „
Net power of motor	12·6 „
Loss in generator	1·68 „
„ line resistance	1·82 „
„ leakage	0·71 „
„ motor	2·07 „
Sum of electrical losses	6·31 „

TABLE II.—RESULTS OF INTEGRATION OF CURVES, Plate 1, Fig. 2.

Total water-power	20·63 HP. hours.
„ electrical-power developed by generator	10·86 „
Net power of motor	7·82 „
Loss in generator	0·88 „
„ line resistance	0·65 „
„ leakage	0·52 „
„ motor	0·90 „
Sum of electrical losses	2·95 „

TABLE III.—RESULTS OF INTEGRATION OF CURVES, Plate 1, Fig. 3.

Total water-power	13·9 HP. hours.
„ electrical-power developed by generator	4·71 „
Net power of motor	3·62 „
Loss in generator	0·40 „
„ line resistance	0·14 „
„ leakage	0·39 „
„ motor	0·165 „
Sum of electrical losses	1·1 „

TABLE IV.

	First Journey.	Second Journey.	Third Journey.
	Tons. cwt. qrs.	Tons. cwt. qrs.	Tons. cwt. qrs.
Gross load	28 12 3	21 18 0	8 16 0
Mean speed in miles per hour	5·7	7·2	11·3
Total energy of water in foot-lbs.	60,291,000	40,860,600	27,522,000
Total electrical energy developed by generator in foot-lbs.	35,871,000	21,516,000	9,332,400
Net mechanical energy developed by motor in foot-lbs.	24,928,200	15,493,500	7,170,900
Sum of electrical losses in foot-lbs.	12,493,800	5,841,000	2,174,700
Loss in generator in foot-lbs.	3,343,000	1,735,800	801,900
„ leakage	1,420,300	1,029,600	775,500
„ resistance of line in foot-lbs.	3,613,500	1,296,900	287,100
„ motor in foot-lbs.	4,098,600	1,791,900	326,700
Total work done against gravity	11,867,400	7,356,800	2,858,300
„ „ „ friction	13,060,800	8,136,700	4,312,600
Mean tractive force, exclusive of gravity in lbs. per ton	28·9	27·4	37·1

TABLE V.—PERCENTAGES.

	First Journey.		Second Journey.		Third Journey.	
	Of the Water Power.	Of Total Power of Generator.	Of the Water Power.	Of Total Power of Generator.	Of the Water Power.	Of Total Power of Generator.
Water-power . . .	100·0	..	100·0	..	100·0	..
Generator-power . .	59·5	100·0	52·6	100·0	33·9	100·0
Net motor-power . .	41·3	69·4	37·9	72·0	26·1	76·8
Loss in generator . .	5·5	9·3	4·2	8·0	2·9	8·6
„ leakage . . .	2·3	3·9	2·5	4·8	2·8	8·3
„ line resistance . .	6·0	10·6	3·2	6·0	1·0	3·1
„ motor . . .	6·8	11·4	4·4	8·3	1·2	3·5

[DISCUSSION.

Discussion.

Dr. E. Hopkinson.

Dr. EDWARD HOPKINSON explained the locomotive car and trucks by models, and also exhibited a model of the automatic gate-opener referred to in the Paper. It had not been expected, he said, that gates would be required at all, but the Government Inspectors insisted upon them. The cost of a gate-man would have been a considerable item in the working expenses of the line, and accordingly Mr. Barcroft had devised the automatic apparatus, which had worked without the least interruption, occasioning no difficulty, except when the tank got frozen. The Author also explained a model of the overhead conductor and collector. The copper wires, were only No. 4, B.W.G., but they were sufficient for transmitting from 20 to 25 HP. A section of the channel-steel conductor was also shown, a piece of the driving-chain, and a piece of the underground conductor. The chain difficulty was perhaps the greatest of any, and it had been overcome entirely by the chain constructed by Mr. Hans Renold.

Mr. Kincaid.

Mr. JOSEPH KINCAID said the elucidation of the subject of electricity as a motive power on railways and tramways was to him very interesting, as he was often called upon to advise on the motive power used on tramways and road-railways. With reference to the use of flangeless wagons, it was interesting to note that the same principle had been applied in another way in some of the road-railways in Staffordshire, where there were wagons running without flanges. These wagons were drawn from the tramways to the works or factories by horses, and when running on the tramway rails they were carried on flanged wheels, which, by an easily applied mechanical arrangement, lifted the wagon off its flangeless wheels. A very large amount of goods traffic was carried on the road-tramways in Staffordshire by those wagons. They carried about 4 tons, and in the course of the year they enabled the tramway company to receive a large amount of additional income. He had no doubt that in future a considerable extension of the system would be adopted on tramways, whether worked by electricity or by other force. Reference had been made to a Paper by Mr. Hanscom on Cable Tramways, giving results obtained from measurements on seven different lines, and comparing them with the results obtained at Bessbrook. He thought it was hardly fair to compare the working of old, and in some cases obsolete, methods of cable-haulage, with results of the more perfect system of tramways made under the guidance

of the Author, and worked by electricity. It would have been Mr. Kincaid. more instructive to have made the comparison with the results of the more recently constructed cable tramways, than to take the average result quoted in the Paper. In 1884, in the Market Street lines of San Francisco, the power absorbed by the cable, as compared with the power absorbed by the cars and passengers, was in about the proportion of $\frac{2}{3}$ of the total power required to $\frac{1}{3}$ of the total power; but two years later, when the number of cars was very much increased, the proportion was 50 per cent. for the cable, and 50 per cent. for the cars and passengers, showing a result much more favourable to cable haulage than the comparison made by the Author. He wished to call attention to the results shown by the Frankfort-Offenbach Electric Tramway, where it appeared that the power for working the tramway was 164 HP. for the use of twelve cars, a very large amount of power, although the tramway was constructed and worked by electricity with overhead wires, which was considered one of the best modes of application. He did not know whether the Author could show any better results in his system than those obtained in the case of the Frankfort line, which had been worked for many years with considerable success.

Mr. KILLINGWORTH HEDGES remarked that the Author had given Mr. Hedges the results of batteries in America, but he had not stated what the batteries were. He should be glad to know what system of batteries was referred to, as he thought the efficiency stated was lower than had been obtained here. He had not had any direct experience with batteries under the same conditions as those pointed out in the Paper, but taking batteries as a means of obtaining power, he had obtained a great deal more than 3,700 watts per ton. He had made a number of experiments in order to test thoroughly the battery of Mr. Bailly, a French engineer, which was known as the Phoenix, and found that the plates would last a great deal longer than three years, which, taking the 40 per cent. depreciation estimated by the Author, would be more than could be expected of the batteries quoted as examples. He should be glad to know if that depreciation had been calculated on the particular cells which gave 3,700 watts per ton, or calculated generally by experiments on storage-batteries. Mr. Bailly's battery was a great advance for power purposes, or rather it went back to the principle of the old Planté battery, which was more suitable for power than the batteries now so successfully used for lighting purposes, especially if the lead-positive plate was done away with and a zinc plate substituted, because there was then a great saving in weight

Mr. Hedges, and a gain in electromotive force. The electromotive force of a lead and zinc couple was 2.6 volts, as against 2.1 with a lead and lead couple, and the weight of the zinc plate was only a quarter of the lead.

Professor
Forbes. Professor GEORGE FORBES congratulated the Author on the way in which he had worked out the system, and applied the details to the special purposes of the case with which he had to deal. In working out any case of electrical traction there were, of course, special points favourable for special cases. At one end of the scale there were electric tram-cars running on the street, and at the other trains running, not on the street, but on a specially-prepared permanent way; and the Author's method occupied an intermediate position between the two. In a great many points he had admirably selected the best means for fulfilling his object. In a system of electric traction there were several different ways of applying electricity to the motor. It might be carried, after the method adopted by the Author, by means of conductors from a generating station; and that could be done by a conductor laid parallel with the rails, or by an overhead conductor; or, thirdly, storage batteries could be carried. He agreed that storage batteries were more expensive than fixed conductors, but there were many cases in which the employment of storage batteries was desirable. Especially was that the case with the ordinary street tram-car, where any system which might be adapted for laying a conductor conveying a current was sure to be objectionable. A self-contained car on the streets was much more applicable than any other system proposed. It had had several trials in this country and in other parts of Europe. When in America recently, he was glad to see that the application of storage batteries to tram-cars had been taken up with the same spirit as had been shown in the general application of electricity to locomotion. Indeed, he had been surprised at the enormous progress in America in regard to electric locomotion, as compared with the half-hearted way in which the subject had been dealt with in England. It was, however, a good augury for the future that a Paper on the subject had been brought before the Institution, so as to lead the attention of engineers more fully to the application of electric traction. There were one or two minor points in the Paper on which he desired to ask a few questions. For the conductor of the current, the Author had applied an iron rail supported on wooden insulators. That had been done on previous occasions, and in those cases the connection had been made from rail to rail by means of a couple-piece U-shaped. The Author riveted it on to the rails. In most cases

of electric work a mere rivet from iron to copper would not be sufficient to prevent oxidation, and eventually it became a bad electric joint. He should be glad to know whether there had been sufficient experience to warrant the belief that the joint described would be a good one for permanent use. The over-head collector was extremely interesting. It was surprising to hear what a large current could be taken from a loose contact with the wire, and with so little injury to the wire. He would also ask what were the shape and position of the brushes relatively to the commutator of the motor, the motor being adapted so as to be reversed without change of brushes. The cost of the system explained was said to be less than the cost of steam would have been. In order, however, to make a fair comparison, the cost of the water-power should be given, and it did not appear in the Paper. Perhaps the Author would state whether the water-power cost anything; and if so, how much. In all tram-cars where there was a locomotive, the general system had been to detach the locomotive from the car; but in many cases the motors had been attached both to the front and back bogies. In the present case the locomotive was complete and separate in itself, but it bore half of the weight of the car in addition, and thereby gained additional adhesion, which seemed to be a considerable point in its favour. There were many different methods of gearing the motor to the driving-wheels. Each of them had its disadvantages, and there was, he thought, room for improvement in that direction. This seemed to be the first application of a combination of toothed-wheel gearing with chain gearing, and the results were consequently very interesting. In electric-tramway work, in designing a motor the desire had generally been to reduce the weight, and make it as compact as possible; and he must say that for ordinary street traffic the more compact and light the motor was the better. In the cars which had been most successful the motors were placed under the floor, completely out of sight, and at the same time were made as light as possible, so as not to add to the total weight to be carried. While it might be admitted that the Edison-Hopkinson dynamo was as efficient a dynamo as had been made, there was no doubt that the dynamo with two legs was not the lightest type that could be constructed, and at first sight the employment of that type seemed to be an objection to the system; but considering the great weight of the whole train, and the necessity of adhesion to the rails, he thought it was quite unobjectionable to have a heavier motor than absolutely necessary. The Author had used iron for main conductors. No doubt when the design was arranged

Professor
Forbes.

Professor the adoption of iron was the best expedient, but when copper was so much cheaper, as it was last year, possibly he would employ that metal instead. There was no doubt a very great future for electric tramways. It had been conclusively accepted in the United States, that electric traction was cheaper than horse traction, whether conductors or whether accumulators were employed. There were, however, further applications for electric locomotion. The subject had been hinted at by the Author in his preliminary remarks, and experiments should be carried on in the direction of supplanting steam locomotives on underground railways by a system of electric traction. Electricians were looking forward with hope to the time when power would be applied to every wheel of a train, in which case, undoubtedly, speed could be increased with safety beyond the present limits, owing to the absence of reciprocating movements and unbalanced momentum in the electric motor.

Mr. Preece. Mr. W. H. PREECE said there was one point in the Paper to which he ventured to take some exception—that part in which the Author drew a comparison between the system of working a line like the Bessbrook and Newry tramway by means of storage-batteries, and the system which he had described. When the Author alluded to the cost of storage-batteries in working such a line as the Bessbrook and Newry, he replied that he was not aware that any electrician had ever proposed to work such a line with storage-batteries. Storage-batteries were better adapted for tramways in towns where the gradients were not very great and the load light, and where they would replace horses, steam and cables. The application of storage-batteries and electric currents to the working of tramways was by no means in an experimental stage; it had reached the practical stage. He had a list of the various lines in Europe and America worked by that method,¹ but he would

¹ ELECTRIC TRAMWAYS IN GREAT BRITAIN.

Town.	Line.	Conductor.	Length.	System.	Power
			Miles.		
Blackpool .	Blackpool Tramways .	{ Buried central rail Rails }	2	{ Holroyd Smith }	Steam
Brighton .	Brighton Beach . . .		1	Volk . .	Gas
" .	{ " and Shoreham Tramway }	..	4	{ Electric Traction Syndicate (accumulators) }	Steam

confine his remarks to the question of the application of storage Mr. Preece. batteries to the working of tramways. Batteries possessed a great many advantages. They enabled the existing rails and rolling-stock to be used; they involved a considerable amount of economy in the permanent way, especially in maintenance; they were noiseless, smokeless and odourless; they were clean and safe, and they did not involve the use of the great amount of space now required for stables and appurtenances connected with horses. But there was one remarkable power which they possessed—they answered automatically to any call made upon them for extra power in ascending gradients. Again, while they were not in use they were not consuming either material or energy; they

ELECTRIC TRAMWAYS in GREAT BRITAIN—*continued*.

Town.	Line.	Conductor.	Length.	System.	Power.
Glynde . .	Glynde Claypits . . .	Open	Miles. 1	Telpherage	Steam
London . .	{ North Metropolitan Tram- ways (Stratford and Manor Park) . . . }	..	4	{ Elieson (ac- cumulators) }	"
Newry . .	Bessbrook and Newry .	{ Raised central rail }	3½	Hopkinson	Water
Portrush .	Portrush and Bushmills	{ Raised side rail }	6	Siemens .	"
Byde, I. of W.	Ryde Pier.	Rails	¾	" .	Gas

ELECTRIC TRAMWAYS on the CONTINENT.

Amsterdam.	Cortverloren Park . .	Overhead	½	Siemens .	Steam
Berlin . .	{ Lichterfelde (Berlin-An- halt Railway) . . . }	Rails	1.6	" .	"
Brussels .	Tramways	..	..	{ Accumulators (Julien) }	"
Charlotten- burg . . }	Spandauer Rock . . .	Overhead	..	Siemens .	"
Cologne .	Tramways	..	..	{ E.P.S. Accu- mulators (Hüber) }	..
Frankfort- on-Main . }	{ Frankfort to Offenbach Railway }	Overhead	4.1	Siemens .	Steam
Hamburg .	Tramways	..	..	{ E.P.S. Accu- mulators (Hüber) }	..
Hohenzollern	{ Hohenzollern Colliery (Upper Silesia) . . . }	Overhead	½	Siemens .	Steam
Vienna . .	{ Moedling - Hinterbruel (Austrian Southern Railway) }	"	2.8	" .	"
Zaukerode .	Zaukerode Mines, Saxony	"	½	" .	"

Mr. Preece. were independent of weather; and, above all, they cost less than any other method of locomotion. He had taken the figures from a great many authorities, and, from all the statements which he had received, it appeared that the average cost of working a tramway by horses was 7d. per car-mile, by steam 6d., by compressed air 5½d., by electricity, whether applied by continuous conductors or

ELECTRIC TRAMWAYS in AMERICA.

Town.	Line.	Conductor.	Length.	System.	Power.
			Miles.		
Appleton, Wis.	{ Appleton Electric Street Railway }	Overhead	4½	{ Van Depoele, 5 motor cars	
Asbury Park, N.J.	{ Lea Shore Electric Raily. }	"	4	{ Daft	
Baltimore, M.D.	{ Union Passenger Rail- way Company . . . }	"	..	{ "	
Bellevue, Pa.	{ " " " " " }	"	½	{ "	
Binghamton, N.Y.	{ Washington Street and State Asylum Electric Railroad }	Overhead	5½	{ Van Depoele	
Denver, Col.	{ Denver Tramway Company }	Conduit	4	{ Short-Ne-smith, series	
Detroit, Mich.	{ Detroit Electric Rail- way Company . . . }	Overhead	2	{ Van Depoele, 4 motor cars	
"	{ Highland Park Railway Company. }	"	3	{ Van Depoele, 2 motor cars	
Gratiot, Mich.	{ Gratiot Electric Railway Company }	"	..	{ Van Depoele, 1 motor car	
Ithaca, N.Y.	{ Ithaca Street Railway Company }	"	..	{ Daft	
Kansas City, Mo.	{ Kansas City Electric Rail- way Company . . . }	"	..	{ Henry	
Lima, O.	{ Lima Street Railway Mo- tor and Power Company }	Overhead	6½	{ Van Depoele, 7 motor cars	
Los Angeles, Cal.	{ Los Angeles Electric Railway Company . . }	"	5	{ Daft, 4 motor cars	
Mansfield, O.	{ " " " " " }	"	..	{ Daft	
Montgomery, Ala.	{ Capital City Electric Street Railway Company }	"	11	{ Van Depoele, 20 motor cars	
Port Huron, Mich.	{ Port Huron Electric Rail- way Company . . . }	"	2½	{ Van Depoele, 3 motor cars	
Richmond, Va.	{ Richmond Union Pas- senger Railway . . . }	"	..	{ Sprague motors	
St. Cathar- ine's, Ont.	{ " " " " " }	"	6	{ Van Depoele	
Scranton, Pa.	{ Scranton Suburban Rail- way Company . . . }	"	2½	{ Van Depoele, 3 motor cars	
Wichita, Kan.	{ Wichita Riverside and Suburban Railway Com- pany }	"	4	{ 6 motor cars	
Windsor, Can.	{ Windsor and Walkerville Electric Railway Com- pany }	"	1½	{ Van Depoele, 1 motor car	
Woonsocket, R.I.	{ Woonsocket Street Rail- way Company . . . }	"	..	{ "	

by storage batteries, $3\frac{1}{2}d.$; so that the cost of working tramways Mr. Preece. by storage batteries as opposed to horses was exactly as 1 to 2. There were no doubt disadvantages connected with batteries, which were always quoted by gentlemen opposed to the introduction of electricity for town purposes. It was said that they were objectionable because they possessed weight. But so did horses. The average weight of a horse was about 15 cwt.; so that the total weight of the horse-flesh used for drawing the tramcar was $1\frac{1}{2}$ ton, which was the weight adopted for storage batteries. The weight of storage batteries was applied in a better place than the weight of the horse; it was frequently placed underneath the seats and well distributed, and to a certain extent utilized. Then, again, it was said that batteries were objectionable, because they led to a waste of considerable time in being charged. So did horses; they required to be charged with food and fodder, one form of energy which was afterwards applied for traction-purposes. The battery was charged by means of a current, and when once charged it did not want water or any other aid to enable its energy to be properly digested, and afterwards properly used. It was further said that batteries were wasteful, inasmuch as they lost a quantity of energy. So did horses. The energy supplied to horses was wasted by processes, which prevented its being properly utilized in drawing cars along the roads. Again, it was urged that a considerable amount of time was lost in changing batteries. So was time lost in changing horses. It was also said that the life of a battery was seriously against its use. The same objection might be applied to a horse; and, strange to say, the useful life of a horse and the life of a storage-battery were much the same, each lasting about four years when applied to the drawing of tramcars. Taking the work done by those two methods of traction, the result came out thus: $1\frac{1}{2}$ ton of storage-batteries would do work at an average rate of 4·5 HP. for six hours. Two horses would not do that. He took the unit of HP. and the actual HP. as synonymous, though they were by no means so. The unit of HP., now unfortunately used, was meaningless and stupid, and he hoped the day was not far distant when 33,000 lbs. raised 1 foot high per minute as the unit of power would be abolished, and something more scientific and exact be adopted. Nevertheless, $1\frac{1}{2}$ ton of batteries would for six hours do certainly three times as much work as two horses. Again, with regard to the price, the price of a horse and the price of a storage-battery came out at about the same figure, namely, £60 per ton. Considering, therefore, the fact that storage batteries would propel a car 45 miles

Mr. Preece. with one charge, there was very little to choose between the use of storage-batteries and the use of horses, unless the question was regarded merely as of pounds, shillings, and pence. The measurements given by the Author and others showed that in working a tramcar upon a gradient of, say, 1 in 50, they were really calling upon the horses to do work that was an absolute cruelty. It was easy to show that, in working a tramcar at 6 miles per hour up a gradient of 1 in 50, each horse was called upon to do 3 HP. work. It was no wonder, while they were called upon to do such work, that their life in drawing tramcars in towns was so very short. Looking at the subject from that point of view, he believed storage-batteries would be found of immense service in working tramcars in towns. The batteries themselves had by no means reached perfection, but they were now very practicable. He had used them in lighting his own house for the past four years, and during the last two years there had never been a failure or accident of any sort. Of course, however, the use of batteries in lighting a house was a very different thing from the use of batteries in moving a car. It was subject to constant changes, constant agitation, and difficulties not met with in engine-rooms and battery-rooms. Still, he thought that a storage-battery was absolutely practicable, and that its durability was equal to that of a horse. The Author had so thoroughly exhausted the subject of using electricity for working tramways, that he had left very little for others to say. His practical experience at Portrush, as well as at Newry, had been a lesson to the whole world, and wherever the system had been carried out it had been generally upon the lines already virtually dictated by him. There had, however, been a good deal of nonsense written and talked about the utilization of waste power. An enormous amount of money had been spent in trying to extend waste power to great distances. Not very long ago a scheme was bandied about in the City of London, proposing to utilize the waste power of Niagara as far even as New York, but it was a very simple thing to show that it would not be economical. Even when there were millions of HP. running to waste, as in the case of Niagara, it would not be economical with present appliances to carry it to a greater distance than 32 miles. In France, Mr. Deprez had been making an enormous number of experiments in endeavouring to transfer power to distances of 20, 30, or 40 miles, but nothing had come of them. All such questions in England had been treated somewhat with disdain. The whole matter had been virtually brought forward by Sir William Thomson, and all scientific men like Dr. Hopkinson,

the Author, and others, knew that it was far cheaper to carry the coal from a colliery district to the place where it was wanted, than to convey the energy of the coal by means of wire. When wire was used, in the first place capital was required, and, in the next place, an annual sum for maintenance. Wires could not withstand gales of wind, except with the expenditure of a considerable sum of money, and the experience of this country in maintaining wires against gales, even the small wires used for telegraphic purposes, showed that it was almost impossible to maintain a wire along roads in working order for less than 18s. per mile per annum. Taking the cost at £1, 7 miles of wire would cost £7 per annum, which was about the cost of a horse-power in the neighbourhood of London. In considering, therefore, the transmission of power to a distance, the transport of the mass of the coal had to be considered, the transport of its energy by wire, and also by means of a storage-battery. In transferring the energy of coal by means of wire it was only possible to utilize as a maximum 50 per cent. of the energy; but with batteries 80 per cent. could be transmitted, so that in reality it was cheaper to transmit the energy of coal by storage-batteries than by means of wire, and it was cheaper still to transmit the energy of coal by transmitting the coal itself, allowing it to exert its own energy in carrying itself. The question of the utilization of electricity for transport purposes was not a sentimental but a purely practical one. It was now in the region of pounds, shillings and pence, and the Institution was much indebted to the Author for communicating his practical experience in connection with the Bessbrook and Newry Tramway.

Mr. J. H. GREATHEAD noticed another comparison in the Paper to which he should like to refer, namely, the comparison with wire-rope traction. The Author had contrasted his system working at Newry with the system of wire-rope cable working in San Francisco. He hoped that the Author would forgive him for saying that he hardly thought the comparison a fair one. The cable lines in San Francisco were constructed under most difficult conditions; the gradients of most of the lines were exceedingly steep, 1 in $5\frac{1}{2}$, and, in some cases, 1 in $4\frac{1}{2}$, and the cable was continually and suddenly changing its direction. The blocks of buildings were about 412 feet square, and at each crossing of a cross-street there was a level portion about 70 feet long. Therefore the lines going up those precipitous hills had to traverse gradients of 1 in 5 or 6, then a level portion of 70 feet, and then another steep gradient, ascending perhaps 70 or 80 feet

Mr. Greathead. in 412, then another level portion, and so on. Under those circumstances the cable system seemed to be the only one capable of being applied for traction on street surfaces. It was much handicapped from the fact that the pulleys used to change the direction of the cable had to be necessarily very small. In ascending, each change of the cable from the inclined to the horizontal had to be accomplished by a small supporting pulley, and again the change from the horizontal to the inclined had to be made by a still smaller depressing pulley. Notwithstanding those difficulties, however, the tramcars were carrying many millions of passengers annually at a uniform speed of from 6 to 8 miles an hour, both up-hill and down, with perfect safety. He did not know whether the Author would propose to establish an electric system under those conditions, but it might be useful to consider how far the comparison held good. The Author had referred to some figures given by Mr. Hanscom, from which he concluded that the efficiency of the electric system at Newry was much higher than that of the cable system in San Francisco; everything depended on what his system was compared with. Mr. Hanscom's observations simply extended to the power necessary for hauling the cables, and not to the power necessary for hauling the effective load. The figures he had given, as to the power necessary for hauling the effective load, were deductions from certain assumptions. According to Mr. Hanscom, the resistance of the cable, which was the only thing he observed, varied considerably between the first cable line constructed and the last. The resistance per ton of the first, viz., Clay Street, was 205 lbs., whilst that of the McAllister was 94 lbs. There was a great variation also in the weight of moving machinery. Taking the whole of the moving machinery, the resistance on the Clay Street line was 84 lbs. per ton, on the McAllister 38 lbs., and on a third line 30 lbs. Where there was a continuously-running cable and varying traffic, the relation between the power employed in carrying the cable, and that employed in carrying the traffic, must of course vary with the traffic, and the whole value of the Author's comparison depended upon what was the traffic accommodated by the cable line. Mr. Hanscom had given some cases where the traffic was such that the efficiency was over 50 per cent., much about the same as the Author claimed at Newry. In the figures given of the resistance in San Francisco, no account was taken of the effect of gravity. The up lines and the down lines were upon the same incline, and the carriages were connected with the same cable, so that the traffic going up was

balanced by the traffic coming down; and again no account was taken of the power expended in getting the car into motion. Those two points were neglected in Mr. Hanscom's calculation, and also in the Author's comparison. He did not imagine that anyone would propose to apply the electric system to San Francisco, or to apply the continuously-running cable system to Newry, to take five or six trains a day in each direction; but he would ask the Author to imagine an electrically worked line established in Clay Street, and the difficulties in connection with the working of such a gradient overcome. The first hill rose 307 feet in a distance of 2,889 feet; there were six level portions of 70 feet. The speed would be 6 miles an hour, taking five minutes for ascent or descent, with a two-minute service. With an electric line the friction, taking the Author's figure of 28.9 lbs. per ton equal to a gradient of 1 in 80, would represent a rise of 36 feet, the resistance of gravity would be represented by 307 feet, the power employed in accelerating would be a small matter, about 4 feet. The total resistance would equal a lift of 347 feet, and that would represent 95,640 foot-pounds per ton per minute, or an average of 2.9 HP. per ton. If of that ton only 12 per cent. was taken as representing the weight of the motor (as at Newry), the HP. for moving 1 ton of effective load would be 3.25. The indicated power resulting from that, taking the efficiency of 54 per cent., would be 6 HP. per ton. Then it might be assumed that the train could be arranged to run back by gravity. But, of course, when the gradients were so steep, the power of the motor would have to be much greater in proportion to the total weight than it was in the first journey at Newry. Suppose the proportion to be as on the third journey at Newry, then the total weight would be 8.8 tons, and the weight of the motor 3.5 tons; and the average net power of the motor would be 8.8 tons multiplied by 2.9 HP.; in other words, the effective power of the motor necessary to take a ton up that hill would be 25 HP., and the maximum would be considerably in excess of that, and as much as the Author's motor could accomplish. The effective load being 5.3 tons, and the power of motor per effective ton 4.8 HP., the indicated power would be nearly 9 HP. per ton for taking the load up the hill and bringing it down again, assuming the return journey could be safely accomplished by gravity alone. How would that compare with what the cable was doing? It was not necessary to give all the figures, but he would take the friction of the cars at 20 lbs. per ton, as Mr. Hanscom had done, in order to keep up the comparison which the

Mr. Greathead. Author had made. At 6 miles per hour, and with a two-minute service, the length of cable to each car would be 1,056 feet; the weight of the cable would be $1\frac{1}{2}$ lb. per foot, or 1,580 lbs. for each car; the weight of the effective load would be 5.3 tons, as at Newry, including car, dummy, and passengers. The weight of the cable would be $13\frac{1}{2}$ per cent. of the effective load, say 15 per cent. The friction of the cable was 200 lbs. per ton, or more than double that on the latest line given by Mr. Hanscom. The total power required per ton of effective load would be the friction of the car, corresponding to a gradient of 1 in 112, making a lift of 25.8 feet; the friction of the cable 200 lbs. per ton, equal to a gradient of 1 in 11, thus $\frac{1.5}{100}$ ton, multiplied into $\frac{25.8 \times 11}{11}$ feet = 1 ton lifted 39.4 feet. The three accelerations as before = 3.9 feet. The total resistance would thus be 69.1 feet. The indicated HP. per ton would therefore be 0.94, and for the return journey the same, so that the total indicated HP. would be 1.88 per ton of effective load up and down. Thus the cable system, by an expenditure of 1.88 indicated HP., accomplished as much work as the electric system could accomplish by 9 indicated HP. In passing, he might remark that in the foregoing calculation the proportion of power employed in the cable system in hauling the effective load was only 43 per cent. of the total indicated, while the proportion in the electric system was taken at the figure claimed by the Author, 39 per cent., and yet the latter required five times as much power as the former in that particular case. Also, the 43 per cent. calculated power was on a cable line much within some of the figures given by Mr. Hanscom. As to the actual work at Newry, it was satisfactory to find that, with a locomotive weight of only $3\frac{1}{2}$ tons, 28 or 30 tons could be hauled at a fair speed up a gradient of 1 in 50. That appeared to be a considerable advance on anything that had been done in this country in the same direction, and from some calculations he had made he was satisfied that with more weight on the driving-wheels much better results could be obtained. In the diagrams of the working of the line, on the second and third journeys, no stoppages and startings were given; but on the first journey there was one stoppage and two starts. In the first start on a level a speed of 5 miles per hour was attained in five minutes, and the horse-power expended was about an average of 14. In the second start, up a gradient of 1 in 50, the speed obtained was 4 miles per hour in three minutes, with an average expenditure of 27 HP. Against the given average resistance of 28 lbs. per ton, the speed at the first start should

have been attained by $5\frac{3}{4}$ HP., instead of 14. There was a Mr. Greathed. gradient of 1 in 50 at the second start, and in that case, instead of 27 HP. the speed should have been attained by an expenditure of only 11 HP. Either those speeds should have been attained, or the resistance must have been very much greater at the beginning. In the first start the resistance would have been 75 lbs. per ton, and in the second 130 lbs. per ton. Of course he could not suppose that there was such a resistance as that, and he could only conclude that the result was due to the slipping of the driving-wheels on the rails. That would indicate that, for making a fairly good start, the weight on the driving-wheels was not sufficient for the line at Newry. Taking the start from Mill Vale, 4 miles per hour in three minutes, with 27 HP. the tractive force would be $\frac{3}{10}$ of the weight on the driving-wheels, and taking the start at an earlier stage, say in the first minute, it would appear that there must be a tractive force equal to the whole weight on the driving-wheels. He imagined, therefore, that in that particular instance the Author had not sufficient weight on the driving-wheels to accomplish a fairly good start. He would suggest that, for obtaining a better start, more weight should be utilized on the driving-wheels, possibly by having a motor at each end of the car, or the adhesion should be in some other way increased. The effect would be to give a still higher percentage of power usefully employed than the Author was now able to claim. With a heavy traffic, and frequent stoppages, the power of attaining speed rapidly was of the greatest importance, and in doing this on the Metropolitan Railways in London, perhaps two-thirds of the effective power of the locomotive was employed, and was subsequently dissipated by the brakes. As to the cost per train-mile, of course the value of the figures given depended entirely on circumstances. In the case in question, it appeared to him that the circumstances were exceedingly favourable, because 56 HP. was obtained at an expense of only £140 a year—very much below the cost of steam-power. He thought that Mr. Preece must be much under the mark in saying that a horse-power would only cost £7 a year in the neighbourhood of London.

Mr. NORMAN SCOTT-RUSSELL said that the Paper had not touched upon the mechanical and engineering difficulties to be contended with in tramways, and he proposed to confine himself to that subject. It was impossible in English streets to employ overhead wires, or conductors laid on the ground or a few feet above the ground. It was necessary, therefore, to adopt one of two

Mr. Scott-
Russell.

Mr. Scott-
Russell.

systems, either a conductor in a channel between the rails or under the rail or otherwise, or else accumulators. The conductor, or the direct system, was no doubt the most economical, because less work had to be done, and it could be done in a more economical manner. It had been tried at Blackpool to some extent successfully; but he believed that great difficulties had been encountered in regard to the conductor, of which the insulation was continually breaking down. He did not think that tramway companies would be justified in adopting such a system, and running the risk of the whole traffic being stopped through failure of the conductor. Even supposing that those difficulties were overcome, he thought the open-channel plan did not present any advantage over the cable, and he doubted whether it could be worked more economically or reliably. Other plans might perhaps be suggested for overcoming the difficulties to which he referred, and he hoped that something would be said with regard to a plan of Mr. Frank Wynne's, where the conductor was placed in a closed channel. With reference to the accumulator system, he failed to see the drift of Mr. Preece's observations and comparisons between the weights of horses and the weights of accumulators. He did not know whether, in the case of the electric car, he proposed to carry the accumulators in front of the car, or whether in the case of the horse-car he had any idea that the horses would be inside. Of course the drawback generally felt, with regard to the weight of the accumulators in a car, was that it added to the amount of work to be done, and made the car so heavy that on the present lines, which were laid for cars of small weight, it was necessary to carry a weight 50 or 100 per cent. heavier. He had always been told that an accumulator weighing 1 cwt. would develop about 1 HP. for an hour, so that for a car requiring 4 HP. for half a day's work, there would have to be thirty-two accumulators. With the ordinary two-horse cars used in London, the weight would be about $8\frac{1}{2}$ tons, which was too heavy for the existing horse-car lines. That showed the importance of keeping down weight. Perhaps accumulators would hereafter be found of less weight. Some engineers had proposed to place the car on bogies on eight wheels, but that was acting in a vicious circle. Because the car was heavier more accumulators were required, and the dynamo had to be made heavier, and eventually the weight was too great for the line. With reference to the gear, on the Bessbrook line chain-gear had been used. He confessed that he had a prejudice against it, for he did not understand how a chain could be made that would not stretch,

and when once it stretched it got out of pitch with the teeth, and must produce a great amount of wear. He was in favour of the worm-wheel originally devised by Mr. Reckenzaun, or, if that could not be used, a simple pinion and wheel, as adopted with great success by Mr. Sprague in America. With regard to the subject of cost, a previous speaker had stated that the cost of electricity was only half that of horses. If that could be proved satisfactorily, electricity would be adopted immediately on all the lines in London; but he thought that most people who estimated the cost of electricity left out one great item, namely, that of repairs. In mechanical traction, whether by steam, by compressed air, or by cable, repairs formed one of the principal items of cost; and in regard to electricity, there was at present no experience to rely upon. He hoped some trustworthy information would be obtained from electricians, and that the matter would be discussed on proved facts as to the weight, power, and durability of accumulators.

Mr. Scott-Russell.

Mr. A. L. LINEFF observed that the electrical world was much indebted to the Author of the Paper for the very comprehensive description of the Bessbrook and Newry line, and of the accurate tests applied to it to ascertain the actual losses in working and the efficiency of the line. To any practical engineer it would be evident that it had been thoroughly well constructed. The insulation resistance of the conductor seemed exceptionally high, and certainly more than might have been expected in a system where a rail formed the outgoing conductor and was fastened almost direct to the sleepers. The decrease of resistance during wet weather, according to his personal experience, seemed almost abnormally small. A fall from 1,000 ohms in dry weather to only 250 ohms per mile in wet weather was an exceedingly enviable result for any electrical engineer. According to the data in the Paper, the individual resistance of each insulator was nearly 1 megohm in dry weather and never fell below $\frac{1}{4}$ megohm in wet weather, when the insulators might be covered with dirt or snowy slush. Some four years ago, when the late Professor Fleeming Jenkin experimented on the Telpher line at Weston, Mr. Lineff tested the line three times a day during nearly four months; the fall and rise of insulation resistance were exceedingly sharp and ranged from 2 megohms to 3,000 ohms, the line being only $\frac{1}{4}$ mile long, with twenty supports in all. In another series of experiments, made during the present autumn on an overground conductor, the variation in the insulation gave a ratio of maxima as 35 to 1. A ratio of 4 to 1 as mentioned by the Author was a

Mr. Lineff.

Mr. Lineff, surprisingly good result. There were weighty reasons to strengthen the conviction of an engineer that electricity would shortly be applied on a large scale to traction on railed roads. The managing directors of tramway companies and of some railways were perplexed how to make the two ends meet, and to give the shareholders some return, even very modest, for their money. Steam, compressed air, ammonia, and many other devices had been tried as a substitute for horses; yet all such attempts did not solve the question definitely, and in many cases substitutes could not be adopted, horses still being used on tramways. One of the previous speakers had made a very ingenious and elaborate parallel between accumulators and horses. Such comparison might be very complimentary to the horse, but not to accumulators. The horse was the most expensive of power-producing machines, and, if a change were intended, something much more economical than the horse must be substituted. It was interesting to ascertain the real value of horse-power on tramways. The custom was to calculate the cost of horses per car-mile, which was very convenient to compare this item of expenditure for various tramway companies, but for engineers it was lacking in precision. They wanted to know what was the cost of 33,000 foot-pounds per minute supplied by horses. According to Mr. D. K. Clark, M. Inst. C.E., the average cost of horsing per car-mile was $5\frac{3}{4}d.$ This was before the year 1880, and he believed the cost now was considerably less. From the returns of the North Metropolitan Tramways for 1886, the horsing per car-mile cost only $4.03d.$, which was perhaps an exceptionally low figure. The average number of passengers per mile was $6.8 + 2$ (driver and conductor) $= 8.8 \times 160 = 1,408$ lbs. $= 0.63$ ton $+ \text{car } 2.4$ tons, or the average weight of the car loaded, say 3 tons. The tractive effort was 25 lbs. per ton; average speed 4.5 miles per hour—

$$\frac{75 \times 4.5 \times 5,280}{60 \times 33,000} = 0.91 \text{ HP.-hour};$$

or for 1 mile $\frac{0.91}{4.5} = 0.2$ HP.-hour, the cost of which was $4.03d.$,

and therefore the cost of 1 HP. $\frac{4.03}{0.2} = 20.15d.$

which represented a value of about 2 cwt. of coal. At the same time the cost of steam-power produced on a large scale was never more than $1d.$ per indicated HP., including all expenses and depreciation of plant. The introduction of steam on tramways brought

with it the same defects as were noticed on railways, only still more Mr. Lineff. accentuated. These were enormous increase of dead-weight¹ as compared with useful load; comparatively small and therefore uneconomical engines, with very high figures for renewal and repairs; more expensive permanent way, and quicker wear and tear of rails, besides the sanitary and other inconveniences unavoidable with the use of steam. Rope tramways had certainly this advantage in common with tramways where the motive force was the electric transmission of power, in that the energy was generated at a central station, and therefore at a very moderate cost. Yet they had to carry a considerable dead-weight in the form of a heavy cable, and to overcome the friction of a great number of moving pulleys, sheaves, etc. He agreed with Mr. Kincaid that the figures mentioned in the Paper with reference to cable tramways were somewhat antiquated. The experiments made this year on the Chicago City Cable Roadway gave rather more satisfactory results, and the power required to drag the cable alone was only 40 per cent. of the whole power (1,022 HP.) generated at the station to move three hundred cars heavily loaded. If the experiment were made on a smaller scale with the average load of passengers, of course the efficiency would be smaller. On the question of electrical transmission of power as applied to tramways, a rather vexatious problem presented itself. Should continuous conductors or accumulators be used? Electricians and non-professional people interested in tramways were divided into two distinct camps, theoretically hostile to each other. Unfortunately there were as yet no reliable data with reference to the life, and cost of renewals, of accumulators on tramways; but it was known that they were heavy. Yet sometimes even a rough estimation was of value for practical purposes, and he had recently prepared an estimate when giving his advice on a new tramway that was to be worked electrically.

¹ Merryweather, Rouen	$\frac{3}{14} = 0.22$
Bristol condensing locomotive	$\frac{16}{200} = 0.08$
Hughes, Wantage Tramway	$\frac{1.5}{13.2} = 0.11$
„ Bristol	$\frac{1.5}{14} = 0.14$
„ Lille	$\frac{3}{16.5} = 0.18$
Perrett, Dublin	$\frac{1.5}{10.5} = 0.14$

The following Table was calculated for various lengths of line Mr. Lineff. and various numbers of cars :—

COST OF CONDUCTOR AND ACCUMULATOR PLANT.

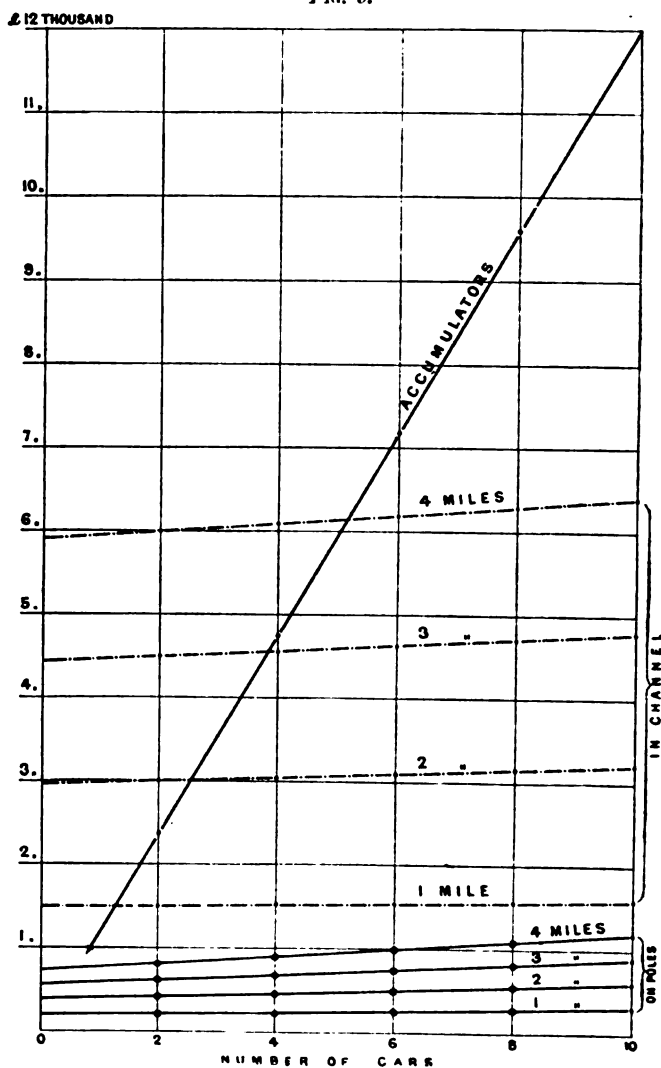
Length.	Two Cars.			Four Cars.			Six Cars.		
	A.	B.	C.	A.	B.	C.	A.	B.	C.
1 mile . .	200	1,500	2,400	225	1,525	4,800	250	1,550	7,200
2 miles . .	400	3,000	2,400	450	3,050	4,800	500	3,100	7,200
3 „ . .	600	4,500	2,400	675	4,575	4,800	750	4,650	7,200
4 „ . .	800	6,000	2,400	900	6,100	4,800	1,000	6,200	7,200

Length.	Eight Cars.			Ten Cars.		
	A.	B.	C.	A.	B.	C.
1 mile . .	275	1,575	9,600	300	1,600	12,000
2 miles . .	550	3,150	9,600	600	3,200	12,000
3 „ . .	825	4,725	9,600	900	4,800	12,000
4 „ . .	1,100	6,300	9,600	1,200	6,400	12,000

The values in this Table had been used to prepare Fig. 9, p. 238. The ordinates represented the cost, and the abscissas the number of cars. The four thinner lines at the bottom of the diagram represented the cost of conductor placed on poles for 1, 2, 3, and 4 miles. The four dot-and-dash lines above represented the cost of conductor in a slotted underground channel. The diagonal line across the diagram represented the cost of accumulators, and was independent of the length of the line, but was very much dependent on the number of cars running. This diagram showed :—(a) That wherever an aerial conductor could be used, the accumulator system could not compete with it, however small the traffic, if the length of the line did not exceed, say, 10 miles. (b) That for heavy traffic the accumulator system could not compete even with the expensive underground continuous conductor. (c) That in each case, where an increase of traffic might be expected, the continuous conductor was preferable, as a trifling extra outlay in copper imparted great elasticity to the line with regard to the number of cars which could be worked on it. (d) That the accumulator system could be advantageously applied in towns on comparatively long lines with a small number of cars running, which was, of course, an exceptional case. Fig. 9 did not pretend

Mr. Lineff, to give with great accuracy the actual cost of individual systems ; but it showed at a glance the characteristic features of each,

FIG. 9.



COMPARATIVE COST OF CONTINUOUS CONDUCTORS AND ACCUMULATORS.

and their relation to each other with regard to the capital outlay. The application of electric traction to railways was a question

of great importance. It was an open secret that the Metropolitan Mr. Line^d. underground lines were needing a radical change. Not only was the public choked by the vitiated air; but, what was more to the point, the shareholders began to suffer through the competition of omnibus and tramway companies. The railway engineer might certainly point with pride to the fact that the consumption of fuel on those lines was under 30 lbs. per train-mile; but what was the amount of useful work done for it? Take as an instance the Metropolitan District Railway; the weight of the empty train was 92 tons; of the locomotive 47 tons; of a full load of passengers, 31 tons. The average number of passengers per train-mile was only twenty-seven, or about 1·5 ton; add 50 per cent. to arrive at the actual number, which would bring the useful load to 2·25 tons, and the ratio of $\frac{\text{paying load}}{\text{dead load}} = \frac{2\cdot25}{139}$ or, only 1·6 per cent.

Railway engineers could not be blamed; they did everything to make their power-producing machine as economical as thought, care, and great experience could make it. But the power was not suitable for the purpose. In order to reduce the cost of fuel and wages,¹ the railway engineer had only one way open to him: to increase the size of the locomotive, and therefore to run heavier trains. The consequences were:—crammed trains for a few hours in the day, and almost empty ones during the remaining hours; slow service, immense waste of power, enormous wear and tear to the permanent way by locomotive wheels with a weight of about 15 tons on each axle, and so on. The whole system seemed to be an illustration of acting in a vicious circle. With an electric plant, the aspect of working a railway would be entirely changed. The power would be generated at a central station or stations, and, therefore, under most economical conditions, with the least expenditure of fuel, attendance, and stores. The trains could be reduced to one or two carriages, starting in the busy hours of the day at intervals of one minute or even

¹ Mr. J. S. Jeans has given in "Railway Problems," p. 146, the following Table of expenditures incurred for locomotive power in 1885.

London and North Western.		Great Western.
Wages . . .	57·0	56·7
Fuel . . .	35·2	34·2
Water . . .	1·0	4·6
Oil, Stores . .	6·7	4·4
	99·9	99·9

Mr. Lineff. less, and of four to five minutes during the remaining hour. In fact, the whole train service could be arranged to a nicety in accordance with the average requirements of the traffic. A separate heavy locomotive would be useless, as the motor could be fixed under the car or on the bogie; this alone would increase the efficiency, or the ratio of useful weight to dead weight, to at least five times its former value.¹ The work of driving and firing would be simply reduced to the turning of the switch in the guard's compartment, and therefore a great saving of wages would be at once effected. Moreover it must be remembered that a dynamo or motor was kinematically one of the simplest mechanisms, having merely two journals with a rotating shaft and no reciprocating parts or motion of any sort. As a consequence, the cost of repairs of an electrical plant must be much less than with locomotive power. He thought it was quite time for the two great metropolitan railway companies to look into the matter more closely, and to give means to the electrical engineer to work out the problem. An investment like this would be of much greater benefit than the extension of existing lines on the old plan.

Mr. Kapp. Mr. GIBBERT KAPP observed that, in his remarks on the importance of quick starting, Mr. Greathead had aimed at establishing the superiority of the cable system over electric traction; but he had overlooked the fact that electric motors were the very things to enable a quick start to be effected. The point had not received much attention in the discussion, but the Author had referred to it in his Paper, where he had shown that with a steam-locomotive the power which could be exerted was limited by the size of the cylinder, the length of the stroke, and the steam-pressure; whereas with a dynamo the power was almost unlimited, it being simply a question of a sufficiently low resistance, and a sufficiently large supply of electricity, to get almost any torque into the spindle which could be utilized by the adhesion on the rails. In that connection of course the carrying of batteries in the car was an improvement, because it added weight and increased the tractive force. One speaker had said that the batteries did not seem to be very successful; but he had that morning received a

¹ To refer to the above example for the Metropolitan District Railway, the introduction of electricity as motive power would alter the useful work thus:— A train of two empty carriages, 20 tons; motors, &c., gear, 2 tons; full paying load, ninety passengers, or 6·6 tons. The efficiency with full load would be $\frac{6·6}{22} = 30$ per cent., half load $\frac{3·3}{22} = 15$ per cent., quarter load $\frac{1·65}{22} = 7·5$ per cent., as compared with 1·6 per cent. the present ratio.

letter from Philadelphia, where the system, introduced some years ago by Mr. Reckenzaun, was in use and working perfectly well. The first car had already run several thousand miles without a hitch, and two others had been put on and had run with the same result. On a rough computation there were now six hundred cars building in America on that system. With regard to the enormous power available for a spurt at starting, it no doubt had its disadvantages. The gear was liable to break; and to compensate in some measure for the strain, several gears had been introduced. That chosen by the Author did not compensate for it; it was as rigid as if it were simply a spur-gear. In Germany ropes were used for the first motor shaft, and sometimes chain-gear for the second. In Brighton a link-belt had been employed. An American device was to hang the motor on a spring, so that at the first turning on of the current the motor was slightly depressed, and made the motion a little smoother. The Author had spoken of the choice of the motor. The generator was a shunt-wound dynamo working at 250 volts, nearly constant pressure, and an ordinary series-motor had been chosen. The Author had alluded to the fact that a series-motor was not self-regulating, and when the car ran on a level or on a slight incline it was necessary to insert resistance, or the speed would be excessive. Of course it could be made, to a certain extent, self-regulating by putting a shunt-wire on the field, thus having a compound motor with the main wire added to the shunt, not subtracted. The real compound motor was absolutely self-regulating, having a differential winding. The main demagnetized the field, in opposition to the shunt, which magnetized it. But that would not be practicable for a tramway, because the valuable quality of exerting a great static effort at starting would be lost. If compound motors were used at all, they should be so used that both windings should assist in creating the field. In that case the motor would not be self-regulating to any great extent, but constancy of speed was not required. All that was wanted was that the motor should not race to any dangerous degree when going down hill. The Author had said that such a provision was unnecessary, meaning probably that it was unnecessary because something else was provided instead—resistance, which the driver would have to regulate according to his position on the line and to the speed he wanted. But he did not agree with the Author in thinking some other provision against racing unnecessary; for even if a perfect rheostat were provided, the driver might suddenly be taken ill, or lose his head, or the switch handle might come off, and then, if the full potential were on a series-motor, it would race

Mr. Kapp. down at a speed difficult to describe. If it was desired to use a series-motor, he should have thought it would be better also to use a series-generator. In that case it was possible to make the system absolutely self-regulating, and so arrange the speed that it should never exceed a certain limit. All that was necessary was to take two machines, the characteristic curves of which had a certain relation to each other ; so that if the generator was driven at a constant speed, the motor would go at a constant speed whatever the load might be. The only condition necessary for that state of things was that the length of the ordinates, between the two characteristics of the dynamo and the motor at any point, must be equal to the pressure lost by resistance in the whole circuit. He had tried the system some years ago for driving a big circular-saw and other wood-working tools where self-regulation was necessary, and the speed was almost constant. But there was another drawback to the use of a series-motor, which had been brought to his notice at Newcastle, where he saw the motor illustrated in the diagram. There was a running contact along the central rail ; and after the car had started a beautiful blue flash was seen along the rail under the car. It arose from a kind of loose brush contact ; and when he afterwards examined the rail it was pitted in many places. The spark might be called a spark of energy, because the circuit of which it formed a part contained large masses of iron, and the self-induction of a motor of that type was certainly very great ; it had a strong field, and the current was not interrupted ; but it simply formed an arc light. If the motor were shunt-wound the electric energy would be small ; but with a series-motor it was very great, so that if the brush jumped the rail got pitted. He did not know whether that was the fault of the temporarily laid line, or the fault of the system. He would ask the Author whether he had noticed any signs of pitting and roughening of the surface of the central conductor. The kind of motor which would commend itself to most electricians for general use would, of course, be a compound-wound motor ; because two or three motors could be running at the same time on the same line. That was almost a necessity for an electrical service, which never ran very long trains at long intervals, but short trains at frequent intervals. In this case it was impossible to use any nicely balanced series arrangement ; but a constant potential, or nearly so ; and then compound-wound motors must be used. With reference to storage batteries, he thought it was hardly fair to compare storage cars in general with cars driven on the conductor system. Each had its own sphere in which it was useful. With lines of

medium length, from 2 to 4 miles, and with a frequent service, the conductor system was no doubt the cheapest; but with a long line and not a frequent service, it could not compete with the storage system. For town lines either might be used. It depended, first, upon whether it was allowed to put down a central channel in the road. In London, where the streets were so thoroughly honey-combed with pipes of various kinds, it would be difficult to put down a conductor; but even if it could be done, he questioned whether it would pay. It would pay when the line was short and the traffic very heavy. In that case even the slight labour of changing batteries in the car was a consideration, and it would be better to be able to work all day long without having to put the cars back into the shed. To compare the cost of batteries and conductors, he might perhaps take the example given by the Author, and show how the cost would be affected by an extension of the line. He believed that everybody would agree with the Author, that, for the case which he had described, he could not have done better than he had done by putting down a central conductor. Had he worked the line with batteries he would have saved £600, but he would have spent £1,200 for the increased cost of the generating dynamo motor and car. Then there would be the cost of two batteries (one for exchange) and the increased weight of the engine and car, and increased working expenses. The question was whether that would have paid in view of the future extension of the line. Supposing the train weighed 40 tons, and contained 6 tons of storage batteries, and supposing the cells to be small 41-lb. cells, there would be a storage of 94 Board of Trade units; but since such small cells would not be used, it might be said that the storage would be 100 Board of Trade units, or 135 HP.-hours, which the cells would be able to supply to the motor. The average horse-power supplied to the motor with a train of 28·6 tons was 24·4, and for a train of 40 tons 34 HP.; therefore, one charge of the battery would keep the train going nearly four hours. At a speed of 5 miles an hour that represented a distance travelled of 20 miles, or allowing some margin of charge in the accumulator, say a distance of 18 miles, 9 out and 9 home. Then, if the generating station were in the middle of the line it would be possible to work with batteries a line which extended 9 miles either way without any further expense beyond the £1,200 for batteries, and an increase in the strength of the plant. What would be required to work a line of 18 miles with the conductor system? He found that the average loss of pressure allowed on the line was 40 volts. That difference must not be increased, otherwise the speed of the car

Mr. Kapp. would be too great in passing the middle of the line, or too small at the extremities. There should be a uniformity of speed, and the same facility of controlling the car all over the line; therefore, too much pressure should not be allowed to be lost in resistance. Allowing 300 volts at the generating station, and the same loss of 40 volts at the far end, 70 amperes would be required for a train of 28·6 tons; and a conductor four times the size of the one shown, say roughly, costing £700 a mile. Then, in addition, there would have to be the expense of joints between the rails for carrying the return current and more earth plates. At that rate the conductor system would come to £14,400. This system, therefore, would be much dearer. For shorter lengths the difference would not be so great, and the limit at which both systems were equally expensive in the particular case mentioned would be reached if the line were extended to $2\frac{1}{2}$ miles on either side of the charging station. Taking depreciation into account, the limit to which the conductor at 300 volts could be carried would probably be 6 or 7 miles when the generating-station was in or near the middle of the line, but for longer lines the conductor system at that pressure was out of the question; batteries must be used. It might be useful to quote a simple rule which he had received from Mr. Huber, at Hamburg (one of the first to run battery cars), as to determining the amount of energy required to propel the cars. On a tram line in fair condition, and with gradients not exceeding 1 in 25, every 125 watt-hours stored in the battery (so that it was ready to be applied to the motor) would suffice to propel 1 ton for 1 mile. Or, in another form, 1 Board of Trade unit would suffice to propel 8 tons for 1 mile. A simple ordinary car with secondary batteries weighed about 8 tons, so that 1 Board of Trade unit would suffice to propel the car 1 mile. Applying that rule to the case he had been considering, he ascertained that 100 units would drive a train of 40 tons 20 miles. That he had found by taking the figures given by the Author, showing a marvellous coincidence between the results of two investigators in different countries.

Viscount Bury. Viscount BURY said that he should not have ventured to offer any remarks, but for the fact that, during the past two years, he had been one of a small party of gentlemen who had been closely devoting their attention to the subject of electric traction. They had had the advantage of coming into possession, for experimental purposes, of the road from Brighton to Shoreham, about 8 miles in length. Owing to the defective traffic and to certain pecuniary reasons, the road was in an extremely bad state, and therefore afforded a very excellent *corpus vile* upon which to try their experi-

ments. The plan they adopted was to use storage batteries and an electric motor. He had heard a good deal from some of the speakers on the theory of what storage batteries would do, but he was able to state what they really could do and had done. He agreed that it would not do to undervalue storage batteries, which he believed were the electric traction power of the future for tramways. But he could not agree with the first remark of Mr. Preece, that no one would apply electric traction by storage batteries to a line such as that described by the Author. The gradients of that line nowhere exceeded 1 in 50, but it was a short line and there were no very peculiar engineering difficulties about it. The line from Brighton to Shoreham had some sharp curves, and it was altogether in a very bad condition. There were some steep hills, one of them 1 in 38, and two of considerable length 1 in 20, so that it was a good test for the motors applied. The Author had spoken of its being necessary to put an electric motor of 2 tons in weight upon a car, and he afterwards spoke of 8 tons of accumulators. Lord Bury would, in defence of the use of accumulators, on a fitting occasion, challenge the accuracy of these requirements; but direct comparison of weight carried was not necessary on this occasion, because the Author hauled a heavy train from a central station, and Lord Bury's party drove a light car with self-contained means of locomotion. They had used nothing of that kind. He had with him the drawings of the car containing the storage batteries, and the whole weight was 5 tons. The boxes of accumulators weighed 1 ton 5 cwt. (there were eighty boxes), and the motor weighed 6 cwt.; the gearing, the extra strengthening of the car, and the car itself with complement of passengers, made up the 5 tons. The chain-gearing (a specimen of which was on the table), which was adopted after various forms had been tried, was found to answer the purpose very well. The speed varied from 6 miles up to on one occasion 20 miles an hour; the speed usually adopted was about 10 miles. A Board of Trade Inspector was present who ventured for a moment or two to allow the rules in regard to speed to be transgressed. What he had stated was not theory but fact, and he hoped that the members would soon be able to see the method in active operation on one of the great metropolitan lines in London. Hills could be surmounted, speed regulated, and the motive power carried for a considerable time, using a car not exceeding 5 tons. He would state the principle upon which they had thought it wise to proceed. They endeavoured to ascertain the cost per mile of steam-haulage, of wire-rope haulage, of the central rail, and also of horses. Not

Viscount Bury.

Viscount Bury. withstanding the remarks of Mr. Preece, he believed that hardly any tramway company worked with horses or with steam under 5*d.* per mile. 6*d.* per mile was not an average but a very low figure for traction either by horses or by steam-power. He and his friends said that if they could beat 6*d.* per mile they could compete with horses, and could advocate their system before the whole world; but if they could not beat 6*d.* per mile they had better retire and wait for a more favourable time, which no doubt would come, for electrical traction. He would not commit himself to figures for obvious reasons. He would only express his astonishment at Mr. Preece's estimate that the work could be done for 3½*d.*; but it certainly could be done under 6*d.*, and therefore they were in a position to compete with horses and with steam.

Mr. Siemens. Mr. ALEXANDER SIEMENS wished to give some figures with regard to the working of the tramway at Ryde. It was built on exactly the same lines as the one at Portrush, and was therefore fairly described by the Paper. The length of the line was only about ½ mile. It used to be worked by horses. The cost of the hire of horses and drivers (a fixed price being paid), the wages of the conductor, repairs, and incidentals, and oil for carriage-lamps during the six months ending the 31st of December, 1885, amounted to 8·02*d.* per mile; and during that time 5,288 miles were run, seventy-two thousand passengers were carried, and the receipts had been about 1*s.* 4*d.* per mile. For the six months ending the 31st of December, 1886, the tramcars were worked by electricity, and the cars were also lighted by electric lamps. The cost of the gas consumed by the engine (the generating dynamo was driven by a gas-engine, which was more costly than a steam-engine or water-power), the wages of the conductor and boy, the gas-engine driver and assistant, and the repairs, amounted to 6·3*d.* per mile. The miles run were 6,435, the passengers carried one hundred and thirteen thousand, and the receipts had been 1*s.* 7·8*d.* per mile. The repair of the permanent way and office expenses were not included, because they were the same in both cases. The figures which had been placed at his disposal by the Manager of the Company, showed that even in such an unfavourable position, where the train went only a few journeys during the day, and where a gas-engine was used as the source of power, the cost per train-mile had been reduced from 8*d.* nearly to 6*d.*

Mr. Richardson. Mr. GEORGE RICHARDSON said that he was Chairman of the North Metropolitan Tramways Company, and the members of the Institution, without going to Germany or Newry, might, within a

distance of a very few miles, learn for themselves what was being done with electricity in Stratford. During five months ending the 3rd of December, forty-two thousand passengers had been carried on the North Metropolitan electric line. Two engines were used. The Company was not interested in electricity, except that it desired to give all the facilities possible. The line was 2 miles long, and the rail was upwards of 95 lbs. per yard, so as to give a certain stability to the engines (working either by compressed air or electricity) which was not obtained on any other line in the Metropolis. In his opinion it was no use talking of electricity as being applicable to towns where a Vignoles rail was used, or of a central rail as being applicable to London, or any other place where there was a large amount of traffic, and where the skidding would thus give six rails against four. It would therefore be necessary to go to Parliament to get power to bring in a third rail. Notwithstanding what Mr. Preece had said, he thought it would be a very good thing for the Post Office to get a third line put in. If for the 40 miles of line now laid, and in course of reconstruction, the Post Office could compel the Company to put down pipes in the centre, it would make a very fine royalty for telegraph or telephone purposes. His Company had in work the Elieson system, and the contract was 4½d. per mile. He knew nothing about the actual cost. If the work could be done even for 6d. it would be a very good thing; and, if it was in excess of that figure, it would be also a good thing for a tramway company to be able to run cars at any time when the weather suited without paying for forage or anything of that kind. That was the real value of electric motive power as against horse-power. Horses had to be kept whether they were earning money or not. Lord Bury had forgotten to mention that, not long ago, the War Office sent round to the tramway companies to see what could be done in regard to horses, of which there was then a dearth. Mr. Richardson then pointed out to Colonel Lane that the Government had not taken into consideration the possibility of electricity, or some other motive power, being employed, so that the Government might say, "We will take the horses and give you the motive power." The exigencies of the Government might thus be a means of bringing forward the question of electricity or other motive power for traction purposes.

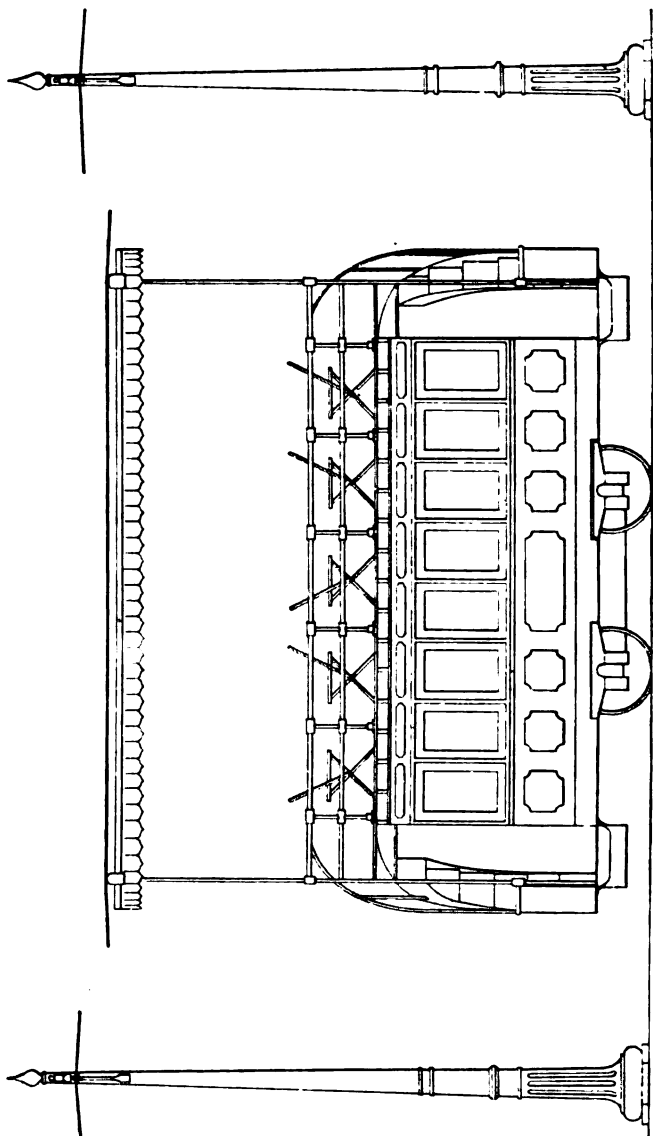
Dr. JOHN HOPKINSON gave some further explanation of his system of overhead conductors for tramways. Overhead conductors had hitherto been used with a roller on a car, fixed in position laterally, or with a runner upon the wire and connected by a flexible conductor with the conductors on the car. In his system the

Mr. Richardson.

son.

Dr. J. Hopkin-son. plan was different. Upon the car, usually fore and aft, were placed cross-bars extending laterally, and consequently having a

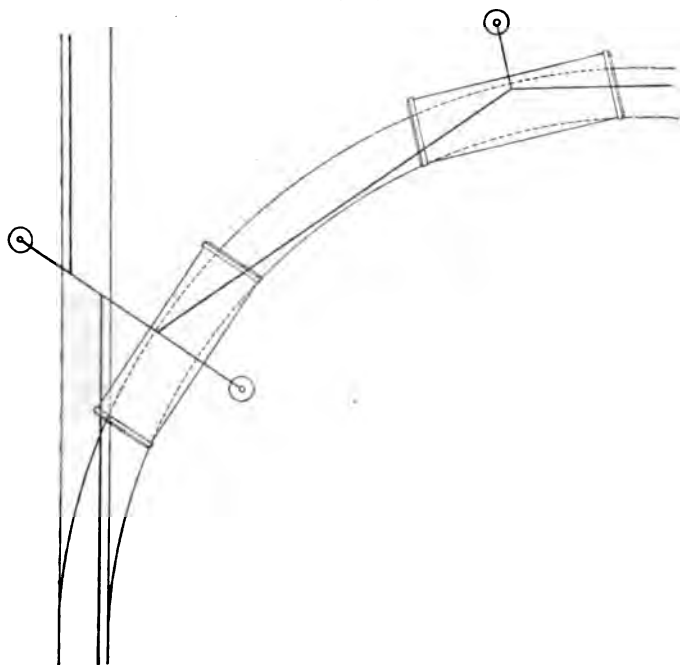
Fig. 10.



width of about 4 or 5 feet; the bars were shown on end in Fig. 10. The consequence was that there was freedom laterally,

so that contact could be made at any point of the width; and Dr. J. Hopkinson there was also freedom vertically, for the bar upon the car lifted the wire, and passed under the insulators. Two bars were usually provided, one forward and the other aft, in order to avoid breach of continuity when the conductor passed one of the posts. That arrangement had advantages in going round curves. Fig. 11 showed the arrangement in plan. The conductor was supported from posts placed on the outside of the curve, and consequently the contact was made with the bar upon the car near the post on

FIG. 11.



the outside of the curve, and remote from the post on the inside of the curve. Fig. 11 also showed the arrangement made at a junction. A cross-bar was shown which supported the conductors, and it would be observed that they were so arranged that the cars going along one line of rails still only met with conductors which belonged to them, passing clear of, without catching over, those which belonged to the other branch. A further arrangement would be required to compensate for temperature in some cases where the head room was to be kept constant. It would be necessary to contrive not that the quantity

Dr. J. Hopkinson. of wire between the posts, but that the tension of the wire should be kept constant, and that the slack wire with increase of temperature should be taken up. This system possessed a number of distinct advantages. Owing to the conductor being overhead, it was possible to use a very much higher potential than would be practicable were the conductor at the ground level. He did not anticipate the least difficulty in using potentials of even 2,000 volts. Again, it was possible to get a much higher insulation with ordinary insulators on posts than with insulators on the ground. Comparing it with the system of overhead conductors previously existing, there were great advantages in junctions and crossings. With the former plan it was a matter of some difficulty to arrange how to pass a junction; but by his method, owing to the lateral extension of the conductor upon the car, so that contact could be made at any portion of the width of the car, it was easy to set in order the most complicated junctions or crossings. The same comparison applied with regard to the conductor below the car. In that case it was necessary to make special arrangements at junctions, in order to avoid short-circuiting the conductor at a junction. The only point that had to be tested practically was whether the overhead conductor would wear well, and that he thought had been conclusively proved by the experience obtained at the Newry tramway, in the one crossing over the length of road where the conductor was overhead. There was there but a single span, but that gave a practical test as well as if there had been a greater length. He thought he might venture to say, too, that the overhead system would have been adopted through the whole length of the Newry line, but for the fact that when he proposed the plan his brother had already ordered material for laying the conductor between the rails. Professor Forbes had remarked upon the great weight of the Edison-Hopkinson dynamo. No doubt the dynamo-machine was a heavy one for its output, but a large portion of the weight lay in the cast-iron bed-plate, which was made substantial and heavy, and in the zinc plate which separated it from the magnets. Some also was superfluous weight in the magnets themselves. If it were a matter of importance to lighten the dynamo-machine, it would be easy to reduce its weight considerably. In the present case he did not think it was of the least consequence. The weight was rather a gain than a disadvantage. One remark had been made from which he almost entirely dissented. Mr. Preece had stated that an efficiency of 80 per cent. could be obtained in accumulators, but not more than 50 per cent. with direct transmission. That comparison was

not accurate, for the 80 per cent. surely was the loss in the accumulators themselves; the 50 per cent. was supposed to be the loss^{son.} in the generator, in the line, and in the motor. As a matter of fact, not only could a very much larger efficiency than 50 per cent. be obtained, but had been obtained, between the power applied to drive the generator and the power obtained from the motor. Apart from the loss by resistance of the line, an efficiency of something like 85 per cent. could be obtained, or even a still higher figure. It appeared, therefore, to him that Mr. Preece was wrong in stating that the efficiency in the case of the direct conductor would be anything like so low as 50 per cent.; it would be much higher. On the other hand, he doubted whether the efficiency between the charge of the accumulator and the electricity which would be obtained from it in practice could be brought as high as 80 per cent. It should be remembered that the loss in the accumulators was to be compared with the loss in the conductor, and not with the loss in the dynamo-machines as well. He might, therefore, say that the efficiency of direct transmission was considerably higher than the efficiency that could be obtained with accumulators. Lord Bury had stated that he hoped to be able to try an experiment with accumulators on one of the great metropolitan lines. The fact was that the Metropolitan Railway was precisely the place in which direct transmission would be free from all objection, and in which the use of accumulators would comparatively be open to very considerable objection. It was possible, therefore, that Lord Bury might be able to try an experiment with accumulators on the underground railways, because he would be able to try it without altering the permanent way. It was certain that no system of accumulators would be permanent upon the underground railways. Mr. Kapp had instituted a comparison between accumulators and the system of direct transmission, in which he showed that when the length of line was great, accumulators would have an advantage over the method of direct transmission. That was perfectly true; but it should be remembered that the figures given were based upon an assumption as to what the potential to be employed might be. He took 250 or 300 volts. By the employment of, say, 1,000 volts, it would be possible to convey overhead with the same loss and at the same cost a current to more than three times the distance which Mr. Kapp had indicated. He forgot at what point Mr. Kapp made out the values would be equal, where the accumulator would lose as much as the overhead conductor; but assuming the overhead system to be adopted, and 1,000 volts to be employed, it would be necessary

Dr. J. Hopkinson. to multiply that by 3. No doubt both the overhead system and the system of accumulators had their respective places. Wherever direct transmission could be used, there, he believed, direct transmission would be used; but there were cases in which contact either overhead or along the ground, or even underground, would be objectionable; and in such cases accumulators had their place.

Mr. Renold. Mr. HANS RENOLD was glad to have an opportunity of saying a few words about chain-gear. In addition to some continental companies he had supplied six distinct firms in England with chain-gear for propelling electrical cars. In one instance this gear had not given satisfaction, whilst in the five other cases it had been found the simplest, the most efficient, and the cheapest means of transmitting power from the dynamo to the comparatively slow-moving car-axles. He could have wished that the time during which these various chains had been in use had been longer. However, on the Bessbrook and Newry line, they had been continually in work for over eighteen months, and from the report received a few days ago they might be doing work for another eighteen months before requiring renewal. In the one case, where the chain-gear had not given satisfaction, the saving of a few pence in first cost seemed to have been the first consideration, and therefore an old-fashioned make of chain had been used in spite of all persuasions to the contrary. Reference had been made to the use of silk ropes, and the worm and wheel as suitable means for transmitting power from the motor to the car-axles. The seven silk ropes as used in Brussels were about $2\frac{1}{2}$ to 3 times wider, and their first cost was said to be fully double that of the chain. A further defect was, that they had so frequently to be renewed. These ropes, acting by friction, had to be made very tight in order to prevent too great a loss of power by slipping, and therefore the pressure in the shaft-bearings became excessive. As to the worm and wheel used in one or two cases, any elementary primer on machine construction would show that it was about the worst medium for transmitting power, where the speed was at all considerable. The contact of worm and wheel might be a point, a line, or a narrow strip of surface, according to circumstances; but even with the very best means of lubrication such surfaces would soon be ground away. This wearing away, which was labour spent in the wrong place, was, however, not the most important objection, it was the great loss of power in the shape of thrust in the worm bearings. His experience as chain-maker was, that hitherto it had not been the want of strength that barred the

way to a more successful and extensive adoption of chain-gear. Mr. Renold. The trouble was that the chains when in use very soon stretched, and thereby got out of pitch and would no longer work on the same wheels. A fairly extensive use of chain-driving began at the latter end of 1878, when he first supplied chains to Mr. John Starley of Coventry, the inventor of the modern tricycle. The power was small, but the conditions under which these chains had to work were similar to, and even more exacting than, those on electrical cars. Two samples of chains exhibited were made on the old system, and it would be seen at once how small the pin-bearings were. Now with two improvements he had been able to increase this bearing surface from six to eight-fold, and also to construct the chain-wheels upon a new principle, which allowed the chain a legitimate wear, or stretch, without thereby giving trouble. Although the cars running from Brighton to Shoreham, as well as the car at Chiswick, had the latest forms of chain and wheel, he had still some further improvements in hand for a more efficient lubrication. For this purpose the designing and constructing of special machinery were in progress. On the Bessbrook and Newry line, the existing wheels that ran in connection with the old system of chains had to be made use of, hence the chains there were not of the latest type. In conclusion he might state the result of an experiment made lately with these chains. The No. V, or 2 inches pitch chain, transmitted 27 HP. at a chain-speed of 1,600 feet per minute. This power was given off by a 6-inch wheel. There was no reason why both speed and pull of this chain could not have been carried still further had it not been for a second and larger chain, meant to transmit the same power to a third shaft at a speed of only 160 feet, failing to act properly, partly on account of its unfavourable position and its too small pinion. He thought nobody would deny that this experiment showed a great step forward in connection with chain-driving. It was no little achievement to have transmitted 27 HP. from a pinion not quite 6 inches in diameter, running at 1,000 revolutions per minute to another shaft only 4 feet distant.

Mr. THOMAS P. GOWER remarked that he had the practical Mr. Gower. management of a system of electrical haulage in London, which had done more heavy continuous work than any system known. He referred to the Elieson system, which he believed was an improvement for general purposes upon the system described in the Paper. With regard to gearing, authorities on chain-gearing stated that the worm and wheel would not stand, and authorities on the worm and wheel said the same thing with regard to chains.

Mr. Gower. He believed that in Brussels, chains had been altogether forsaken in favour of silk ropes. By the Elieson system of gearing the armature, revolving rapidly about 960 revolutions per minute, engaged in a rack; that rack caused the motor itself, which was carried on a vertical shaft, to revolve, and it thus acted as a fly-wheel. The shaft carrying the motor was continued to a crown-wheel below it. That crown-wheel was always engaged with two bevel-wheels on the axle, one of them running loose, and the other was held fast to the axle by means of a clutch, operated by a lever. By that means the motor always revolved in one direction, and, without any reversal of the current, power was obtained to run in either direction. That, for all practical work on tramways, was of the greatest possible advantage, because only in very few places, even in the country, could a loop of 55-foot radius be obtained for engines to run round, and keep always in one direction. The loops, at Bessbrook and Newry respectively, would occupy ground sufficient for about half of Cannon Street Station, and a system depending upon such artificial help as that could never succeed in any but very exceptional districts. He thought when the Author spoke of his system as being generally adaptable, and of the accumulator system as being only occasionally adaptable, he precisely reversed the problem. He considered that the former system was available where there was an abundance of room, and where possibly there was water-power. With regard to the power used, the Author seemed to have at his disposal a constant HP. of about 62, with which he appeared to have done a very small amount of work, computed at 64 miles per day, two hundred and ninety passengers, and 40 tons of weight. With 62 HP. in steam, he thought that amount of work would be considered wasteful in the extreme. In the Appendix the Author had quoted the expenses for six months' work. Wages were put down as £50 18s., apparently for the driver and attendant at the generator station only, amounting to 19s. per week each. Either skilled electricians could be got very cheap, or ordinary labouring men were enabled to look after the delicate mechanism of dynamos and motors. He could only congratulate the Author on such a result, for men of that kind had not been discovered in London. Whether any method of elimination had been used, whether more skilled men had been employed at higher wages, and only the actual time occupied had been taken, he could not tell, but it would be interesting to know how men had been obtained to attend to such electrical work at so small a cost. The water-power was not so economical as would at first sight appear,

because a fixed sum of £12 per month was charged for water rent, Mr. Gower. which appeared to be a somewhat high figure. Taking the expenses for the six months as quoted, which he took to be representative of the whole period of work, they came to 4·2*d.* per mile. There was a significant note at the bottom stating that "the above figures do not include anything for depreciation or for general supervision." Possibly that "general supervision" might include the skilled electrical knowledge and experience that he had ventured to think could not be obtained at many places for 1*s.* a week. He thought, however, that a word had been omitted, and that the sentence ought to read "interest and depreciation." The Author had taken exception to the use of accumulators on the ground of depreciation; but with regard to his own system nothing was allowed, and something only immaterial was spoken of, for depreciation. He would venture to suggest that an elaborate and beautifully formed conductor, such as that shown on the table, joined at every length with copper strips, in order to obtain conductivity, and with the ordinary tram-rails also similarly connected, could not possibly be maintained without considerable expense being incurred for depreciation and repairs, especially as under certain lengths of the conductor a cable had to be laid in order to throw such sections of the conductor out of circuit to prevent accidents at level-crossings and otherwise. In the Elieson system, the annual depreciation for accumulators was reckoned at 30 or 40 per cent. It might be said, however, that the Elieson system had very strong accumulators, and that not a single negative plate had failed in the course of eighteen months' experimental work, or in the six months' hard work on the roads. The positive plates did fail, and from their failure arose the excessive wear and tear of the accumulators. With regard to the other plant, it would be a reasonable estimate to put the depreciation at 15 per cent. per annum. Applying that rule to the Author's system, assuming the 15 per cent. to cover depreciation and also interest on capital, the amount would be £375 per annum. Then, allowing something for "general supervision" (mentioned in words but not in figures), there would be a total of £40 per month, which ought to be added to the Author's estimate of the cost of haulage. That made a material difference, and would bring the estimate of 4·2*d.* per train-mile up to 9·85*d.* He did not think those figures could be questioned. There must be wear and tear of dynamos, of motors and of gearing, and he considered that, including reasonable interest on capital, 15 per cent. could not be considered an excessive estimate. Then, he ventured to

Mr. Gower. suggest that the work done on the tramway described in the Paper had not been very heavy. For purposes of comparison he might mention some figures relating to the work accomplished at Stratford. The Author had had two engines built for occasional, if not constant use at Newry. At Stratford there had been two engines in constant work for the last five months. At Newry, in two years, which he estimated at six hundred and twenty-five days (he believed no work was done on Sundays), the traffic had been on an average of 64 miles a day, or 384 miles per week, seventeen hundred and forty passengers per week, and 240 tons of merchandise. The work done at Stratford had been at the rate of 1,050 miles per week as against 384; five thousand or six thousand passengers had been carried for each engine, or ten to twelve thousand passengers per week as against seventeen hundred and forty; and the gross load had been 12 or 13 tons regularly, the engines having been tested up to nearly 20 tons. That was a comparison which at all events proved that accumulators would do hard work, and that it was impossible for such a system to be put aside in favour of that described in the Paper without further enquiry. With regard to gradients and average current used on the North Metropolitan Tramways at Stratford, in starting on the level there was a consumption of 50 amperes for a second or two; with 7 tons net load there had been taken as much as 55 amperes for a few seconds, but it came down to 25 amperes almost instantly; and in ascending an incline of 1 in 30 the consumption did not as a rule exceed 50 amperes; 25 was the average on the level in fairly good weather. There was, however, a drawback in the extremely dirty state of the road. What was practically a railway line was generally clean, but in the case of tramway lines the cars often ran on dirt instead of on metal, which materially added to the current used. When starting with a load, as was sometimes the case, on the steepest gradient, 1 in 27, for a few seconds the current might reach 70 amperes, but it immediately came down to 50 even on that grade. He should not have said so much but for the fact that what was really a very interesting experiment (at present it was not much more), as described in the Paper, had been assumed as proof that the accumulator system was condemned, and that the system described by the Author would take its place.

Mr. Crompton. Mr. R. E. CROMPTON said that the great interest taken in the Paper under discussion, and in similar Papers in America, showed that the question of the adaptation of electric power to tramcars was a burning one. He thought that it would be a great mistake

to treat the two systems to which reference had been made as Mr. Crompton. rival ones; each had its own separate and particular uses, and it was quite conceivable that a tramway company might employ both with great advantage. Of all systems that he had seen, he thought that none was better adapted for suburban traffic than that proposed by Dr. John Hopkinson—the wire resting on the top of the car. It was extremely simple and cheap, and admitted of the very high insulation described. The way in which the difficulties of crossings had been overcome was admirable, and he did not know of any system more suitable for bringing passengers from a distance of 3 or 4 miles outside a town into the town itself than the system of overhead wires; but he must say that a great deal of the work which engineers had to do, and were likely to have in connection with tramways, would probably be done with a self-contained car, because so many miles of tramways had been already constructed on which full leave would be granted to place such cars, but which would have to be broken up for a subterranean conductor. The pioneer cars in towns were, he thought, more likely to be of the self-contained than of the direct form. That being so, engineers had to consider the reason why the self-contained car had not done better in America and in England. The mechanical questions connected with the cars might be considered as practically solved. He did not propose to enter into the question of the respective advantages of chains and ropes, a matter that had been thrashed out in the old days of traction-engines, and road-engines. The late Mr. Thomas Aveling, of Rochester, first showed what could be accomplished with chains, and how the wear and tear of chains used for traction-engines could be reduced in the way that had been described in the present discussion, so that the great bugbear of the stretching of chains had been already obviated. He thought it might be admitted as a fact, that the mechanical difficulties of running cars on the road by electrical motors had been practically surmounted. The question now was whether a form of accumulator could be put on such cars, which need not have such a heavy depreciation charged on it as practically to prohibit its use. He believed that it could. He had seen the system at work in Brussels, and had also examined the system described by Mr. Gower, and in both those cases he thought the question was answered in the affirmative. Mr. Julien of Brussels, and Mr. Elieson in England, both had steep gradients to contend with, and if they had not absolutely solved the question they had gone a long way in that direction. With such extraordinary inclines and curves as those at Brussels the work could

Mr. Crompton, not be done by horse-power at all; and any one who had seen Mr. Elieson's work, described by Mr. Gower, on the North Metropolitan Tramways, would admit that that gentleman's statement was not in any way exaggerated when he said that the cars ran on dirt more than on rails. The tram grooves were often filled with mud, and he thought it probable that the resistance was very nearly as high as if the car ran on the road itself. The great difficulty, hitherto experienced in fitting the accumulators to the cars, had been in providing against the deterioration of the accumulators from the excessive vibration. Mr. Julien had overcome that difficulty by a particular form of plate, and Mr. Elieson had overcome it in another way. He was glad to hear Mr. Gower's statements as to the wear of negative plates. He was happy to say that there was a gentleman sitting next to him who had told him that he could make a positive plate last for ever. By putting the two together there need be no charge for depreciation. He might be permitted to mention a suggestion that had been recently brought up in America—that, if the motor was designed with the proper proportion of magnets, it would be possible by weakening the field to run it as a motor, and by strengthening the field to convert it into a dynamo; so that whenever it was desired to apply the brake, instead of putting a mechanical brake to the wheels it would be only necessary to strengthen the field of the dynamo and it would begin immediately to pump a current back into the accumulators, or into the overhead wires or mains. That would be an excellent system where there was a good deal of starting and stopping. For the first time the power formerly wasted in stopping would be got back to help the start, or what was much the same thing if it was on the direct system, and there were many cars on the same line, the car that was stopping would be helping the car immediately behind to start. The idea was extremely beautiful, and ought not to be lost sight of by those who were designing motors for that class of car. It would involve slightly heavier magnets, but the loss in that way would be extremely small—nothing in comparison to the amount of current saved.

Prof. Perry. Professor JOHN PERRY had nothing but praise for the system described by the Author. It was true that it was a simple case, but the details appeared to have been carried out very carefully, and it was a distinct gain to have such a Paper brought before the Institution. Such details involved an immense amount of trouble, and numberless mistakes were unavoidably made in the course of all new work. In spite of what had been said with regard to accu-

mulators, he thought that Dr. Hopkinson had made out a very good case for the insulated conductor. There could be no doubt that accumulators had their defects. The conductor had only to be touched, and there was an immediate supply of power. All that was carried was the motor itself. He had a considerable interest in the conductors, and was perhaps therefore prejudiced; but he must say in favour of accumulators that, after having carefully looked at the question, he thought that accumulators would be more used for a considerable length of time for tramway work than the conductor system. They had been greatly improved during the last six years. Professor Ayrton and himself had in 1881, as engineers of the Faure Company, put an accumulator on a tricycle, and had been all about London with it, going up and down Queen Victoria Street, in running the measured mile; they had no work to do in preparing the road, but had simply something to do with the tricycle, which could be taken out and run on any road; no preparation of permanent way being required. At the same time an accumulator car belonging to the company went all over Paris, going from one tramway line to another where permission was granted. No preparation of the tram lines was required beforehand; it was only necessary to prepare the tramcar in the works and to run it out. At that time the accumulators were far from being perfect. The way in which accumulators had formerly to be looked after was something serious. When they were lighting the Grand Hotel at Charing Cross those people who admired the steady working of the lights knew nothing of the trouble that had to be taken with the accumulators. There were most carefully constructed switches which never short-circuited a single accumulator; and yet a ton of accumulators had to be carted away every week, and another ton brought to supply their place. All that difficulty had now been done away with, and accumulators could be depended upon. It was true that a considerable percentage of the first cost was still to be charged for depreciation; but the improvement was continuing, and he thought that the accumulator system would be very greatly used for tramcars, especially in towns. It must be regarded as the pioneer system for towns; at all events, it was the only system which at once replaced horses without its being necessary to do anything to the road. After the accumulators had been introduced into the electric tramcars all over existing lines, then would be the time for the conductor, which had greater chances of ultimate success than accumulators, and which would come in and reap all the profit if the system was so much better. The over-

Prof. Perry.

Prof. Perry. head conductor was certainly a very beautiful contrivance for bridging a gap. He had used a similar appliance in telpherage more than two years ago, but instead of having a stationary hanging wire, he had a hanging wire from one end of the telpher train to the other, which rested in two or three fixed forks, and there was a rubbing contact between the hanging wire of the train and the forks. Mr. Crompton had introduced the subject of the future of electric tramcars. That tempted Professor Perry to say a few words about the lecture, delivered by Professor Ayrton at the Royal Institution in March 1882, with regard to electric locomotion.¹ It had been shown, and nowhere better than in the Author's example, that for a short length of electric railway or tram line very good insulation indeed could be obtained; but the loss became exceedingly great when the length of line was great, and, if engineers thought of having electric railways, they must have some better method of insulation even than that adopted by Dr. Hopkinson. The system of Messrs. Perry and Ayrton was this: the conductor, which leaked, supposing it to be 20 or 30 miles long, was divided into short sections; each section would not leak very much; and if only one section at a time was connected with the dynamo-machine, the insulation of the longest line was as good as that of a very short line. Their system was to bury the conductor near the line or to have a well-insulated conductor, whether buried or not; and that insulated conductor was only connected with the rubbed rail when a train was in the neighbourhood, so that the section behind the train could not leak because it was not connected with the dynamo-machine; the section in front of the train could not leak, because it was not connected with the dynamo; only the section which the train happened to be connected with could leak. The particular method by which the system was carried out was probably well known. Electrical methods as well as mechanical methods had been adopted; but as soon as that method of insulation had been designed, it was found that it led to another important thing, namely, an absolute block system. If, for example, three sections of the line were considered, A B C, which might be of any length, when a train was on section B no electricity was given to section A at all. When the train had left section A it had cut off the electricity; but it had done more than that; by a simple electrical device, it prevented a train which might come on section A from getting electricity, and it was not

¹ Proceedings, vol. x. p. 66.

until the first train had left section B, and went on section C, that Prof. Perry. the section A could get any electricity. As soon, however, as the train on section A got electricity, and ran up again on section B, if the first train had not left section C, the second could not get electricity; the following train could not get within a certain distance of the preceding train; it was immediately blocked. The non-receipt of electricity and short-circuiting the rails was a very different thing from merely being braked. It was as if all the coals and steam and hot water were taken suddenly out of a locomotive. Not only was it given absolutely no power to go on but a very powerful brake was applied. And not only that; it did it automatically, so that there was no chance of an accident due to the engine-driver, indeed there need not be a driver. The model which was shown on the occasion to which he referred five years ago was very interesting. There was a large model on which a goods train preceded an express. The goods train was going at a perfectly steady rate round the line, and the express train was continually making dashes towards the goods train and then stopping; as soon as it came within a certain distance of the goods train it stopped dead, starting again when the block was automatically taken off it. Lastly, it was shown that by that system it was possible to have at an office, whether far from the train or close to it, a map of the line on which a shadow travelled indicating a train, so that it was easy, by studying the positions of the shadows, to tell the positions of the trains. In carrying out the system they had two problems before them. The easy problem, as it might be called, was that of inducing the Directors of the District and Metropolitan Railways to allow them to employ this system on their lines, or of inducing the Directors of the London and North-Western Railway Company to discard all their locomotive plant and convert their line into an electric railway. But they chose a still more difficult problem—to carry out their system on an overhead tramway designed by the late Professor Fleeming Jenkin, thus effecting the conveyance of a continuous succession of skips, containing 2 or 3 cwt. each, at a low rate of speed. He would not go into the question of the troubles they had met with in carrying out the system; he would only say that they had been pretty successful in getting over them, and at the present time there was an overhead Telfer line working at Glynde in the hands of labourers, who were receiving from 19s. to 26s. a week, and who were perfectly competent to do their work. The system had been in operation for the last six months without any accidents, except one to the armature of the fixed dynamo-machine.

Mr. Sennett. Mr. A. R. SENNETT asked why it was necessary to reverse the locomotive? Why should not the bogie be placed in the centre and the car run in opposite directions as was usually the practice with cars not mounted upon bogies? It appeared to him that adhesion might be gained by putting the bogie in the middle of the car. Each end of the car might be supported on two wheels only, and joined by a bogie in the centre. By placing the two pairs of wheels in proper positions, in relation to the lengths of the cars, there might be as much weight as was wanted on the centre bogie. Then again, instead of using a pair of coupling-rods between the wheels of the bogie, for the purpose of increasing the adhesion, Mr. Sennett thought that it would have been preferable to have employed two driving-chains instead of one, the one going to the foremost pair of wheels, and the other as shown by Fig. 4. The advantage of this arrangement would be, that the coupling-rods would be rendered unnecessary, there would then only be half the strain on each chain, whilst there would be the same grip on the rails. Much had been said during the discussion with reference to driving-chains and gear. He thought that no one method of driving could be said to be the best for all cases; but that various systems would have to be made use of according to the conditions of working of the particular line. Where passengers were to be carried on the locomotive as in this instance, for example, one of the chief points to be considered was steadiness in running. The Author, he thought, had acted wisely in mounting the gear upon the bogie, and keeping it as distinct as possible from the body of the car. He thought that tooth-gear was not suited either for passenger work or high speeds. At Frankfort, where tooth-gear was made use of, and this affixed to the body of the car, the motion, especially at starting, was extremely unpleasant, shaking the passengers in a very disagreeable way. With reference to chain-gearing, he could not think it was suited for high-speed cars, but that either steel wire or silk rope would be preferable. Even on the line constructed by the Author, he thought rope-gear might have been employed. As he understood the Author, the working-strain upon the chain was about 1,430 lbs., whilst the maximum strain at starting was 3,400 lbs. Now by using the arrangement of gear Mr. Sennett had suggested, and providing the pulleys with, say, six grooves, the working-strain upon each rope would be only 119 lbs., and the maximum at starting only 284 lbs. He surmised that but little difficulty would be experienced in making wire-rope possessing at once the necessary strength and flexibility. In Germany, at Lichterfelde, such an arrange-

ment of small steel-rope was in use, and the motion, at 20 miles per hour, was pleasant in the extreme, as also was that of the street electric tramway at Brussels, where silk rope-gear was employed. Chain- and tooth-gear doubtless had their advantages for heavy loads and low speeds. He thought the subject of adequate adhesion on electric tramways was a very important one. Unlike a steam-locomotive, the torque upon the driving-shaft was greatest when the electric-locomotive was at rest. Therefore, if the adhesion and gear were properly proportioned, the electric-locomotive could pick up and get away with its load with much greater dispatch than a steam-locomotive. Evidently, therefore, an electric tram-car, with the same attendance, should get through considerably more work in a given time than a horse-car. The chief delay in the working of street cars was due to (1) the very frequent stopping and starting, and (2) the taking up and setting down of passengers. To reduce the delay, powerful brakes, suitable gear for quickly getting up speed, and ample entrance and exit accommodation should be provided. In an ordinary horse-car neither of these was very satisfactory, and he thought that for street cars, to break the car up into compartments, even if they were of the same class, as the Author had done, was a great improvement. In an ordinary London horse-car the proportion was about one exit to twenty-six persons; whilst in a third-class railway carriage it was one exit to ten passengers; whereas by having the car in two portions, and exits at the ends, the proportion for the same number of passengers might be reduced to one exit to seven. With the requisite gear to fulfil the requirements, little difficulty should be experienced, whilst in reference to the brakes, the method pointed out by Mr. Crompton was certainly very ingenious, and would doubtless be found to work very effectively. In order to avoid so many stoppages, at Frankfort the plan had been adopted of receiving and discharging passengers only at those posts which were painted white. This he thought a very good plan having regard to speed of transit and diminished wear and tear at starting; such an arrangement would be of great service at Brussels where the hills were steep. Dr. Hopkinson's system of overhead wires was certainly very pretty. After what might be seen at Frankfort he could not imagine that any city such as Paris, containing beautiful buildings, would allow such an ugly arrangement as at the former city. But Dr. Hopkinson's overhead arrangement possessed the great advantage of lightness, since he merely had to support the weight of the conductors; whereas at Frankfort the split wrought-iron tubes in which the contact shuttles travelled con-

Mr. Sennett. stituted the major portion of the weight carried by the posts. The noise produced by the sliding of the shuttles in the tubes was objectionable and apt to frighten horses. He quite agreed that with Dr. John Hopkinson's system the working of junctions was much simplified. He wished to ask why the conductor was not made as a flat strip, because in that case there would be a much broader surface of contact. The collecting bar struck the edge of a circle, and the contact could not be very wide, besides which, the lateral pressure due to the action of the wind on a thin piece of copper or steel would be much less. As Dr. Hopkinson had used steel on the ground, he should have thought it would have been an advantage to have had the extra tensile-strength of steel over copper for overhead conductors, which had to sustain the weight of snow. It did not appear to him that the form of electromotor made use of by the Author was a convenient one for tramway propulsion, on account of its weight and the form of its field magnets; to devote so large an enclosed space to the motor seemed very wasteful and unnecessary, since nothing was likely to happen to the field magnets which could be attended to on the journey, whilst attention to the gearing could be given most conveniently on the unenclosed bogie platform. With reference to the methods of carrying the electrical energy, he was of the same opinion as Mr. Crompton that the pioneer tram-cars, especially those to run on existing tram lines, should be worked by means of accumulators; but electrical engineers had been hitherto unable to practically examine the matter in the absence of a reliable accumulator. The working of the Julien accumulators at Brussels, however, appeared very satisfactory, a glance at the line showing that this small length had been chosen as it was a difficult one to work by horse traction on account of the steep hills. But he thought that the overhead rubbing contact method possessed so many advantages, such as the ability to employ a greater difference of potentials, better insulation, and lessened liability of stoppage of traffic by snow, &c., that it would be the method employed in the future. There was a great field for elevated electric railways in cities possessing crowded thoroughfares such as London, and he hoped the proposed elevated electric railway for Vienna would be constructed.

Dr. E. Hopkinson.

Dr. EDWARD HOPKINSON, in reply, said that Mr. Gower had appeared as a strong advocate of storage batteries. Dr. Edward Hopkinson had said nothing detrimental to storage batteries; he had only referred to their use in the particular case with which he had had to deal at Bessbrook. It appeared to Mr. Gower very

extraordinary that in the estimate of the cost of haulage given in the Appendix no mention was made of a skilled superintendent for the line, and he had congratulated him upon the fact. He accepted the congratulation, for, since the line was opened nearly two years ago, there had been no skilled man at Bessbrook. He had himself been there only twice during the time. The line was worked by two ordinary unskilled Irish workmen taken from other occupations, one, who superintended the turbine and generator-dynamos, receiving 25s. a week, and the other, the car-driver, 15s. Irishmen were contented with somewhat less than Londoners. He was not surprised at Mr. Gower's astonishment at no skilled superintendent being required. Anyone who had had to do with storage colls knew that they needed a great deal of skilled attention. Mr. Gower next referred to the loops at the ends of the line. The object of the loops was not by any means wholly to let the locomotives run continuously in one direction. At Bessbrook the traffic consisted not only of passengers, but also of large quantities of goods, which Mr. Gower had not to deal with at Stratford. One of the principal objects of the loops was to afford siding room for the goods wagons, and to allow the passenger car to be uncoupled from the wagons, leaving the latter on the line to be drawn off as might be convenient, while the former went on to the platform to discharge its passengers and then proceeded on its return journey. Figs. 2 and 3 showed the arrangement of the loops by which this was effected, and that a large portion of the space occupied by the loop at the Newry end was utilized for sidings. The car could be reversed at any time, and it was reversed constantly in shunting without the least trouble. In Mr. Elieson's system there was a more or less complicated gear for effecting reversal. At Bessbrook it was accomplished by simply reversing the direction of rotation of the armature of the dynamo. Mr. Gower had further referred to the large amount of power required to deal with a comparatively small number of passengers. Bessbrook was not a populous place; it contained only two thousand inhabitants, so that the number of passengers was small; but the line was not intended for merely passenger traffic, it was intended primarily as a goods line and was made as such. It had to deal sometimes with 200 tons of goods each way in a single day. The comparison which Mr. Gower had drawn between the weights hauled on the Newry and the Stratford lines respectively was altogether illusory. In the former case, out of a total of 28·6 tons, the motor and its carriage amounted to 3 tons only, the remainder of the weight being effective load, con-

Dr. E. Hopkin-
son.

Dr. E. Hopkinson. consisting of the goods-wagons with their loads weighing 19·4 tons, and the passenger-car and its passengers; whereas in the case quoted by Mr. Gower, with the exception of a few passengers, he believed the load carried consisted entirely of accumulators. Professor Forbes had asked whether there was not trouble with the riveted connections of the conductor. A few of the copper strips had broken in the loop, and had had to be replaced, but the system of riveting had proved quite satisfactory. At Portrush the connections were made by loops of round copper riveted directly into the conductor, and these had proved a source of trouble, the rivets working loose. At Bessbrook, on the other hand, the connections were formed of copper strips with independent double rivets, and no trouble whatever had resulted. Mr. Lineff, in discussing the insulation of the conductor, referred to the very small increase of leakage in wet weather. He thought that was susceptible of a simple explanation. Where there was a tension of 300 volts upon the conductor and a surface of moisture over each insulator, the moisture was very soon converted into gas, and he believed that therein lay the true explanation of the small increase of leakage during wet weather. Mr. Kapp had also asked in regard to the conductor, whether there was not a gradual pitting of its surface, owing to the current being drawn off by a simple rubbing contact. He had observed slight indications of this in places where the car was frequently stopped and started, but generally there was no pitting of the surface. There was a certain amount of sparking, but it appeared to be entirely due to the rust on the surface of the conductor. There were no blue sparks, but simply yellow sparking such as might be expected from a rusty surface. Mr. Kapp had endeavoured to show that the system of continuous conductor would not be applicable if the line were extended at each end for another length of 4 miles. In the particular case in question there would, however, be no difficulty, because at both ends the ground was comparatively level and the amount of power required would be small. If the character of the line were the same throughout, then certainly the proper course would be to adopt a higher potential as Dr. Hopkinson had pointed out.

In reference to the subject of gearing, he wished to correct an observation of Professor Forbes, because it might give a wrong impression. The gearing at Newry was not used there for the first time. Sir William Siemens introduced it at Portrush, and it was there that he had obtained his experience of it and his confidence in it. Chain-gear, if not rightly constructed, was most

difficult to work with, and the wear and tear of all the working parts was excessive; but if the chain were once constructed strong enough to take any load to which it might be subjected, and to stand the high speed at which it had to travel, there would be no stretching, it would not get out of pitch, and it would work a long time. One of the chains at Newry had been working eighteen months, and as yet showed no signs of wear or stretching. There was one real advantage in chain-gear, namely, that it allowed the body of the motor to move relatively to the axle, so that the rise and fall of the springs did not interfere with the smooth working of any part of the gear. Mr. Scott-Russell had described Mr. Sprague's system of gear by a pinion on the motor shaft rolling upon a spur-wheel upon the axle, the motor itself being carried on a bearing upon the axle of the car, the other end being supported by a link. He had had that system drawn out three years ago for the Bessbrook motors; but it involved several disadvantages. The space was too confined, and it was impossible to get sufficient ratio of gear between the axle of the dynamo and the axle of the car.

Mr. Greathead had referred to a point which certainly at first sight appeared to be of some importance. He had pointed out that the power required in starting on the level and on the incline of 1 in 50 (Plate 1, Fig. 1) was altogether out of proportion to the speed attained. This was not due to an error in the observations, but to the method on which the curves were drawn. In reality the speed, instead of rising uniformly from rest to the first observation recorded, would rise suddenly at first, and then gradually increase to the latter value. With this explanation it would be found that the figures were approximately, though not quite, correct. Professor Forbes had asked a question as to the position of the brushes on the dynamo. They were placed nearly at the neutral point. No difficulty arose from sparking, and there was no necessity to shift them unless the load was very heavy, when they were slightly advanced. He had been taken to task by Mr. Killingworth Hedges for saying that accumulators would work at the rate of about 5 HP. per ton. Directly afterwards Mr. Preece, who was an undoubted authority on accumulators, put the figure at 3 HP., and a little later Mr. Scott-Russell, who had disclaimed any knowledge of the subject himself, had put it at 20 HP. per ton. When the authorities disagreed he would not attempt to step in.

Numerous observations had been made on the cost of working the line. He thought he had been discreet upon the question of cost, having relegated it altogether to the Appendix, considering it a

Dr. E. Hopkinson.

Dr. E. Hopkinson. matter of particular and not general interest and applicability. It appeared to him to be absurd to compare the cost of working one line with the cost of working another by another system. The only really valuable comparisons of cost were such as the one given by Mr. Alexander Siemens, who had stated the actual figures for the same line when worked electrically, and when worked by horses. The conditions were so essentially different, that what might be costly for one line might be cheap for another. In the present case the reason of the low cost was no doubt the cheap water-power, and that was entirely the reason for adopting the system employed. If there had been no water-power the line would have been worked by steam. Lord Bury had referred to the great weight of the motor, and had stated that his motor only weighed 8 cwt., while the Edison-Hopkinson weighed 2 tons; but he forgot to mention that the latter acted as a locomotive for a train of cars and trucks, while the former had only to propel a car containing twenty or thirty passengers. Mr. Greathead had objected to the results given in Mr. Hanscom's Paper on wire-rope traction on the San Francisco lines being quoted for the purposes of comparison with electrical traction. He was sorry if he was unfair in doing so, but he was not aware of the much better results obtained since. However, he did not know that his reference was after all unfair. The San Francisco was the first cable-traction line, and the line described in the Paper was the first electrical line treated upon that system, on which goods were carried on a large scale.

The discussion had brought into prominence one point, of great importance, which he desired to emphasize. It had shown the futility of advocating any particular system of electrical working as generally applicable, without giving due consideration to the particular conditions to be met. One system might be suitable for one set of conditions, and entirely unsuitable for another set; and any particular system might be easily reduced to an absolute absurdity by applying it under unsuitable conditions. He, therefore, declined to follow Mr. Greathead in supposing the system of a continuous conductor to be adopted upon the lines of San Francisco. He would not even attempt to go into the figures, because, on the face of it, no one would ever seriously propose to try the continuous-conductor system on such lines. The San Francisco hills were so steep—the gradient in one case being 1 in 9, and in some other cases still steeper—that the locomotive would have to be weighted unnecessarily in order to get the requisite adhesion, and that would cut away at one blow one of the chief advantages of

electrical traction. But there were other cases besides lines where grades were steep. He would go to the other end of the scale and take ordinary street tramways. Here, as a rule, the grades were not steep, or only steep for very short distances; but for their successful working certain essential conditions must be fulfilled. First of all, each car must be absolutely independent, and contain its own motive power; the street surface must not be interfered with; and it must be possible to start rapidly and stop quickly; and there must be no nuisance from smoke, noise, or smell. The system of storage batteries very successfully fulfilled these conditions. The wire-rope system could not compete, because if the rope broke all the cars were stopped, and the whole traffic was unhinged. Steam could not compete, because a steam-locomotive was an intolerable nuisance upon ordinary roadways. A continuous conductor could not compete, because that meant interference with the roadway, or else carrying an overhead conductor, which would not be generally permissible. The conditions were all favourable to storage batteries, and storage batteries would undoubtedly be employed. The development of the subject might be safely left in the hands of Mr. Preece, Lord Bury, Mr. Reckenzaun, Mr. Elieson and others, who had given close attention to it, and had already overcome many difficulties, and had few left to contend with except the serious depreciation to which accumulators were subject. But many cases lay between the two which he had mentioned, such, for instance, as the proposed overhead line along the Liverpool Docks, or the Metropolitan underground lines. There again the conditions were different. There must be economical working, because the loads to be carried were heavy; there must be very light motors and light cars, especially in such a case as that of the overhead railways in Liverpool, because it was of the utmost importance that the permanent way should be as light as possible. Each car also should be independent, so that the break-down of one might not necessitate the upsetting of the whole traffic of the line. There should also be freedom from smoke, from steam, and from cinders flying about. In those cases the continuous-conductor system was *par excellence* the best. If its special features were considered, it would be seen how exactly they fitted the conditions to be met. Each car had its own motor, each was independent of the other, and the break-down of one did not necessitate the break-down of all. That was not the case with a wire-rope. Again, there was the lightest possible motor and the lightest possible car, which could not be obtained with accumulators. A heavy motor and a heavy car were

son.

Dr. E. Hopkinson. necessary to carry the accumulators; that meant a heavy permanent way; and much more power was taken in frequent stopping and starting, because of course the power necessary to get up a given speed was proportional to the mass to be moved. Again, steam was not suitable in these cases. The use of steam involved a heavy locomotive, and much nuisance from smoke, cinders, and noise. He did not want to trench upon the ground of the accumulator system, of wire-rope traction, or of steam traction; he only desired to emphasize the special cases that were suitable for the introduction of the continuous conductor. In his Paper he had simply shown what had been done in that direction, and what could be done. He was well aware that the system had not in all its details been carried out in the best possible way; knowledge was only gained by experience; but he thought enough had been shown to prove that the system was applicable to the great schemes of overhead lines and underground railways in large towns which were daily increasing in numbers and importance.

Correspondence.

Mr. Barcroft. MR. HENRY BARCROFT observed that Mr. J. F. Harris, who, as the Managing Director of the Bessbrook Spinning Company, had chiefly controlled the tramway, required that it should be operated without the employment of specialists or mechanics; and, as a matter of fact, the only man taken out of other occupation was the conductor, who had nothing to do with the machinery. The others were men out of work at the time of engagement. The man in charge of the dynamos had formerly been a loom-tenter, whose health would not admit of close indoor employment. The driver had no further acquaintance with machinery than that picked up in handling a steam-crane. The remaining men were without any experience of engines or machinery. He thought this test, after two years' working, afforded strong evidence of the simplicity and completeness of the system. He inclined to the overhead system of conductors, as designed by Dr. John Hopkinson. The electrical joints on ground conductors had, on the Newry and Bessbrook tramway, occasionally required attention, whereas there had been no trouble with the 50 yards of overhead conductor, except at the point where contact was made, and wear at this point had been met by lengthening the line in one direction. The ground conductor also gave trouble when coated with ice or snow, but the overhead was not affected thereby. As to leakage,

the one had little advantage over the other; but the ground conductor, being of steel, would wear longer and probably cost less. The collector first designed by the late Sir William Siemens was very unsatisfactory in working, and a collector of new design had been substituted, which gave no trouble and was much simpler.

Mr. EDWARD PRITCHARD observed that electric motors for tramway purposes in this country were practically in their infancy; four lines only were mentioned by the Author as being worked by electricity, and all of these had continuous conductors. It was, however, a question whether continuous conductors or storage batteries afforded the greatest advantages; and he was of opinion that for street tramways an electric motor supplied with electricity from accumulators was preferable. He recently had an opportunity of making a careful inspection of the Elieson electric motors at work upon the North Metropolitan Tramway at Stratford, and he was much struck with the compact arrangement and effective work of this motor; certainly an electric motor on the storage system had the great advantage of being utilized upon existing tramways without any alteration to the roads. As many objections were now being raised to steam motors, there was a great field for electricians to perfect their system, so that in favourable cases the electric motor could be substituted for the steam-engine; after all, this was, to a certain extent, a question of cost of working. A comparison had been made with wire-rope traction; and he took exception to the Author's remarks under this head. Reference had been made to a report of Mr. Hanscom, on the work of cable tramways in San Francisco, showing that on the average 32 per cent. of the total indicated power only was available for moving the cars and passengers. But it must be borne in mind that the percentage of the total power required for this purpose was of necessity governed by local conditions; and although no doubt the total available power for moving cars and passengers was in some instances as low as 32 per cent., yet in other examples this represented from 65 to 70 per cent. Being professionally interested in works of cable-tramway construction in England, he, in 1886, inspected nearly every important town and city in the United States where cable street railroads were in operation; and, from the opportunities he had of witnessing the indication of the engines at the power depots, he considered the effective power for cars and passengers from 30 to 70 per cent. of the total indicated power, as accurately representing the available power upon the street cable railroads in America. In addition to the power

Mr. Pritchard. necessary to move the empty cable, he found that there was a great disparity in the HP. necessary for each car, which varied from $\frac{1}{2}$ HP. to 4 HP. in addition to the power necessary to move the cable. This disparity was accounted for by the unequal loads upon the severe gradients; also by the nature of the road, as regarded curves and various matters relating to the efficiency with which the work had been carried out. It must be obvious that a comparatively straight road, with carry and curve pulleys all turned up, and the loads upon the up and the down lines equally balanced, was much easier to work than one with tortuous roads, having severe curves, heavy gradients, imperfect workmanship, and unbalanced traffic. Many of the roads in San Francisco had gradients of about 1 in 5; but the cable railroads in Market Street and Valencia were, for a great portion of the distance, of exceedingly light gradients. He combated the Author's statement that the wire-rope system would present less favourable results if applied to the lines similar to the Bessbrook lines, where the gradients were less severe. He would illustrate the working of the street railroad in Chicago; in this city, where the roads were practically level, and where there were many miles of horse, steam and cable tramways, he found, from an inspection of the reports of the South Street Railroad Company, that the cost per passenger upon level roads by that Company was: horse roads, 5.759 cents per passenger; steam roads, 3.905 cents; cable roads, 2.506 cents. The total cost of working cable roads in Chicago was 10.75 cents per car-mile; whilst the receipts upon the same roads represented 21.75 cents per car-mile; thus showing that the working expenses were less than 50 per cent. of the receipts. Prior to visiting the United States and making these inspections, he, like many other engineers, held the opinion that the cable road could only live upon a gradient that could not be worked successfully by steam-locomotives; but his inspection of the level roads in Chicago proved how fallacious such an opinion was. It was after all a question of cost when considered as a commercial enterprise; but it had yet to be proved that traction by electricity could be worked as cheaply as by either cable or steam. The working cost of the Bessbrook tramway, which was upon fairly easy gradients, and which had its motive power, water, provided comparatively free of cost, varied from 3.3d. to 4.2d. per tram-mile, the gross weight of the trains being taken at 30 tons. These figures included nothing for depreciation or general supervision, and the cost of haulage could not under these circumstances be considered satisfactory, when compared with the ordinary steam traction. It

must be borne in mind, of course, that between 30 and 50 HP. was Mr. Pritchard obtainable for the Bessbrook line at a rental of £143 per annum. He knew of no power excepting cable that could be worked more cheaply than steam. The Birmingham and Aston Tramways Company, with which he was connected, had during the five months ending the 30th of November, 1887, worked per train of one engine and one car, approximately 15 tons in weight, at the following cost per train-mile :—

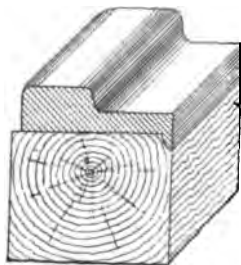
Wages—Drivers, cleaners, &c.	d. 1·19
Fuel	0·63
Water	0·05
Stores	0·30
Total	2·17

The repairs and renewals of locomotives amounted to 1·08d. per mile, making the total haulage expenses, inclusive of repairs and renewals, 3½d. per mile only, and this upon a line having long gradients of about 1 in 20. In conclusion, he thought that until considerable advance had been made in the generation of electricity, it would be impossible to work electric motors where the electricity had been generated by steam-power so cheaply as the steam-locomotive direct; whilst on the other hand, with the service of, say, three minutes' interval, steel-cable traction was the most economical in point of first cost and of subsequent working.

Mr. HOLROYD SMITH had had the pleasure, under the escort of Mr. Mr. Smith. Barcroft, of examining the line shortly after it was opened, and was then confirmed in his opinion as to the high quality of the Edison-Hopkinson dynamo. The behaviour of the generators under the necessarily varying load was all that could be desired, from an electrical and engineering point of view; they were excellent, both in design and finish. As a motor the dynamo was equally good, for this particular application; where a weight was required to give tractive adhesion to the locomotive wheels, a heavy motor might as well be used; but the design and proportion must be considerably modified before it would be suitable for street cars. He took exception to the title of the Paper. The Bessbrook and Newry line was not a "tramway," as the word was now generally used and understood. This line was not subject to other vehicular traffic, and the provision of an extra rail for the flangeless wheels of special trucks did not make it into a "street railway." He supposed the reason why the double rails were used was that they were easily obtainable, otherwise the American

Mr. Smith. tram-rail (Fig. 12) was, in his opinion, more suitable. He was interested to find that the Author had found it expedient to electrically connect the "earth" rails; because, when in his specification for the Blackpool line, he provided for electrically connecting the rails in order to ensure a good "return," some

FIG. 12.



people assumed he had forgotten that the rails would make "earth," and thought he was incurring an unnecessary expense. The Author had shown a vertical section of the Newry line (Fig. 1), in order, probably, to emphasize the steepness of the inclines; for in referring to the Blackpool line, he said, "the track is nearly level." Mr. Holroyd Smith wished to point out that the steepest grade at Newry was 1 in 50, on a curve so wide that it was practically straight; whilst at Blackpool there was a

grade of 1 in 40 on a curve of 63-foot radius. Round this curve he had run a car, with passengers weighing $3\frac{1}{2}$ tons, hauling another behind it, weighing 5 tons, at a speed of 6 miles an hour. When it was remembered that the coefficient of friction on tram rails round curves was about 40 lbs., it would be seen that the Author was mistaken in saying that "in no case has the effective power of any single motor exceeded about 4 HP." He wished also to correct the statement as to speed. The average on the Blackpool line was certainly 6 miles an hour; but this included the numerous stoppages. As an illustration of what could be done there, he once ran a car, seating fifty-six passengers, up the line, stopped five times in the 2 miles, and accomplished the journey in thirteen and a-half minutes. He was pleased to hear that the insulation at Newry was so good; it was better than at Blackpool: but he would point out the special difficulties that obtained there, namely, the frequent flooding with salt-water. When the sea did not flow over the road, the Corporation laid the dust with salt-water; in fact the roadway was in a chronic state of saturation with saline moisture, yet notwithstanding this, the leakage, with a potential of 230 volts, was now only 5 amperes on the whole system. He should have been glad if the Author had gone more fully into the detail of gearing; he could endorse what he said about the good chains made by Mr. Hans Renold, and was inclined to think the difficulty experienced with the first supplied was partially due to the form of wheel employed. It was a mistake to construct the teeth of a chain-wheel on the principle of a rack-and-pinion. On

this subject he would refer to a Paper by Mr. F. A. Griffiths, "On Mr. Smith. the Distribution of Wheel-load in Cycles."¹ Knowing that considerable difficulty had been at first experienced in making efficient contact between the travelling locomotive and the centre rail, he regretted that the Author had not given any details of how this was now accomplished. An arrangement of his own, a combination of rolling and rubbing contact, had been successfully tried by others, in some experiments on the elevated railroads at New York, and he was disposed to think it would be suitable for Newry. He fully agreed with all that the Author had advanced respecting secondary batteries, and was glad that so able a champion had entered the lists in advocacy of the continuous-conductor system.

Mr. J. SWINBURNE expressed his satisfaction that the Author Mr. Swinburne. used a heavy but efficient motor. There was a tendency to insist on the motor being as light as possible in tramway work. Lightness was always obtained at the expense of efficiency or strength. In tramway cars carrying storage cells, the total weight was much greater with a light and inefficient motor than with a heavy one and fewer cells. He considered a properly-designed shunt-machine better than a series-motor. It did not lose its field with heavy loads, nor at starting, if the field-circuit was made first, and a small resistance was inserted for a moment in the armature circuit. It had been pointed out to him, some time ago, that a shunt-machine tended to run at constant speed. The magnetic poles could be designed so that there should be just enough brush lead to make the back induction compensate for the fall of electromotive force over armature-resistance, and that the machine should run at constant speed under constant pressure. In addition to this, a shunt-machine could be wound so that the speed should be very slightly affected by the pressure. A good shunt-motor could therefore run at constant speed with both the load and pressure varying. No such regulation was possible in corresponding cases of dynamos. In addition, the shunt-motor preserved constant speed, even going down a hill. It then acted as a brake, but, unlike a brake, it did not waste power, but returned it to the dynamo. The differential motor was often described in books and papers, but was not made in practice. In fact, it might start backwards. After all, constant power, not constant speed, was wanted. The Author had referred to the facility with which an Edison-Hopkinson machine could be reversed, by keeping the brushes at the neutral point. But this property was by no means

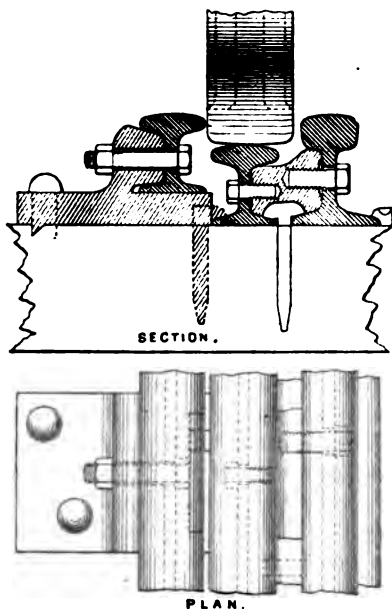
¹ Institution of Mechanical Engineers. Proceedings, 1886. p. 128.

Mr. Swinburne. peculiar to the Edison-Hopkinson machine. Any well-made machine could be used in the same way without sparking. A motor had been made by Mr. Crompton for special work, which was regulated by moving the brushes round the commutator. The calculation of the angle of lead could be dealt with in much the same way as the Author and his brother had dealt with the theory of dynamo-machines. For the last year Mr. Swinburne had been in the habit of working out the action of the armature current. In designing very large machines, such as that recently made for the Cowles process, accurate knowledge of the effect of the armature current was as necessary as a clear understanding of the action of the field-magnet coils.

Mr. Thomas. MR. FRANCIS S. THOMAS said he had been appointed Resident Engineer of the Bessbrook and Newry Tramway in 1883, by the Bessbrook Spinning Company, and carried out the entire laying and construction of the line. As the plate-way scheme had to be adopted, many novel features had to be embodied in the permanent way, mostly at the suggestion of Mr. Henry Barcroft, of Newry. A description of the general arrangement of the permanent way had been given by the Author; but several minor details which had been successfully carried out, were, he thought, worthy of mention. In the first place, it must be borne in mind that the car wheels ran on the inner (higher) rails, and the flangeless wheels on the outer (lower) rails. The flangeless wheels being free to revolve on the axles, and the axles in their turn in journals, made many wearing surfaces, and consequently the wheels could not be always running exactly true, as this varied the gauge. The rails were, therefore, constantly moved from their seatings, and the fastenings loosened. Since the wagons had to run on the roads it was absolutely necessary for the wheels to revolve either way independently of each other, so attention was turned to making the rails more secure. This was done by inserting a cast-iron block made to fit in between the two rails, and secured to them by two set-screws, one through each web. These blocks were placed from 6 to 7 feet apart. A T-headed spike was also used with much success, the flange of the large rail being punched to receive it. When laying the rails this was only driven half way home; the smaller rail was spiked up close on the outside, and the T-headed spike was driven home by the aid of a set inserted between the two rails. A check-rail on sharp curves was also found necessary for the flangeless wheels; and, instead of using the ordinary angle-iron butted close against the outer rail, such as was used in old colliery tram roads, Mr. Barcroft designed a cast-iron chair, and bolted

one of the small rails to them, the chair having a base for it to rest on 1 inch higher than the sleeper, bringing the top of it to the required height above the plate-rail. This answered very well, although it added somewhat to the cost. These arrangements were shown by Figs. 13. The points at the termini were also novel, having to permit both flanged and flangeless wheels passing over them. Ordinary points were used for the flanged wheels with the following arrangement for the flangeless wheels:—If the branch line went to the left, the plate-rail on that side ran round at its

FIGS. 13.



proper level, with a check-rail on the outside; the other plate-rail was given a gradual rise at the points, so as to bring it up to the level of the inner rail. This rail was continued at this level until it reached the crossing plate, after which it gradually fell to its proper level. The check-rail kept the wheels from running off the inside of the curve. To allow the flanged wheel to pass round through the inner rail inside the curve, a special casting was used with a chase in it for the flange to pass through; this was fixed exactly opposite the points. Points were also tried that allowed the flangeless wheels to travel any way over the points, but owing to the small radii used they were not a success.

Mr. Ward. MR. RADCLIFFE WARD stated that the first electric tramcar operated in this country was under his superintendence, and had been referred to in the press early in 1882. He had been requested by Mr. Phillipart to arrange with a London tramway company for a demonstration; and he eventually did so with Mr. George Richardson, the Chairman of the North Metropolitan Tramways, to whose initiative, and to the encouragement given by the board of that company, the present position of electric traction in London was largely due. When he visited the Portrush electric tramway soon after it was open, he was struck with the excellent performance of the collector working on the main conductor, devised by the Engineer of the line, Mr. William A. Traill, both on the conductor itself and at the points when it "retook" the conductor after going over a passing place. It seemed an admirable method of dealing with heavy currents in such cases. He was much interested to learn that the "collection" of heavy currents presented no practical difficulties in electric haulage by the overhead contact arrangements of the Author. There were numerous tram companies in this country whose lines had been laid down with a view to the use of steam-locomotives, and who would not hear of adopting electrical traction if it involved the pulling up of their present excellent permanent way. There were also numerous lines with rails that had been laid many years, and the most judicious way of renewing them would be constantly arising in any case. In discussing the question of electric traction in detail with several large tramway companies, it had been over and over again made clear to him that no case, as to whether the adoption of accumulators or direct transmission was best, could be decided in favour of one or the other without going into all the working details, comparative capital-outlay, &c., in each project. If the most advantageous method of working an entirely new system were being considered, and proper culverts could be constructed, direct transmission would be in a different position to what it was now; but the bulk of cases to be dealt with at present in this country could be examined on no such basis. He considered that 40 per cent. per annum depreciation for the maintenance of accumulators was excessive. The accumulators used for lighting railway trains on the Brighton Railway were probably exposed to as much vibration, if not more, than accumulators on good tram lines. The first railway train ever lighted in this country by accumulators, in combination with a dynamo driven from the axle of one of the vehicles, was fitted and worked under his supervision, acting for the electrical interests, and under the direction of

Mr. Stroudley, the Locomotive Engineer, and Mr. Houghton, Mr. Ward, the Telegraph Superintendent, of the London and Brighton Railway Company. The depreciation of accumulators on tramways very largely depended on their being used in a proper way as regarded the quantity of current taken off, and how, from a given working surface, &c. The practical point for a tramway company was, what was a reliable maker prepared to guarantee? Certainly under fair conditions guarantees could be got at much less than 40 per cent. Broadly speaking, there were two ways in which tramway companies could avail themselves of electric traction. They could purchase the plant, or they could give a contract at so much per mile to a contractor who provided all plant. The latter method was undoubtedly the one that could be most quickly carried out, and which would be most to the advantage of tramway companies who were not very rich, as it gave an immediate opportunity of improving their service and increasing their dividends. If tramway companies had to find their own capital for electric traction, progress would be comparatively slow, and subject to keen competition between various electric manufacturers after the work was once well on foot. To induce a tramway company to enter into a contract, some fair reduction per car-mile must be offered over the present cost. Taking into consideration the constantly increasing extent of tramway work, and the present certain possibilities of electric traction, few branches of industry offered so fair a promise of success at the present time. Dealt with energetically on a sufficiently large scale, there was beyond question an immense field for economy.

Mr. F. J. WARING thought that a few statistics relating to the cost of construction, and of working of the Highgate Hill Cable Tramway, derived from a Parliamentary Return, furnished to the House of Commons in 1886, might be of interest. At the date of that return he believed that the Highgate Hill line was the only tramway, in the United Kingdom, on which the cable system of traction was used. Up to the 30th of June, 1886, the total capital expended was stated to have been £59,277, and this sum was thus subdivided in the return :—

		£.
Expenditure on lines and works open for traffic, including }		
land and buildings	}	38,388
„ on engines		650
„ on cars		2,350
„ on legal and Parliamentary charges		9,994
„ on other charges		7,895
		<u>£59,277</u>

Mr. Waring. The length of the line was 57 chains, 48 chains being double, and 9 chains single track. Thus the capital expenditure had been at the rate of £83,195 per mile of line open, or assuming the cost of a double line to be twice that of a single line, at the rate of £45,163 per mile of single line open. The Parliamentary Return contained also the following statistics relating to the working of the line during the year ending the 30th of June, 1886 :—

1886.	£.
Receipts (wholly from passenger traffic)	3,908
Working expenses—	
Maintenance of way and works	635
Traffic expenses	3,206
Direction and management	317
Rent of offices, stables, and sheds	104
Rates, tolls, and taxes	152
	£4,414

Loss on working, £506.

The number of car-miles run had been 104,331, and the number of passengers carried six hundred and forty-two thousand and eighty-three. From these figures it appeared that the working expenses were 112·94 per cent. of the receipts; that per car-mile they amounted to 10·16*d.*; the receipts per car-mile being 8·98*d.*, the loss was 1·17*d.* per car-mile. Making every allowance for the circumstances which contributed to swell the cost of the Highgate line,¹ it was thought that the necessary high capital expenditure entailed by the cable system of traction could only be justified by a corresponding decrease in the cost of working, which did not appear to have been attained; for, upon a similar basis of calculation in regard to thirteen tramways worked by steam-locomotives, the average cost of working during the year ending the 30th of June, 1886, was 9·19*d.* per car-mile. Comparing cable tramways with those on which electrical traction on the continuous-conductor system was adopted, even assuming the mechanical efficiency and the cost of working to be equal, he thought, where circumstances permitted a choice, that the balance of advantage lay with electrical traction. The cost of the wire cable necessary as the transmitter of power, in the one case with its tube, pulleys, and rails forming the groove, must be largely in excess of the simple conductor, and means of insulation with the copper connections, necessary in the other.

¹ Minutes of Proceedings Inst. C.E. vol. lxxix. p. 165.

13 and 20 December, 1887.

GEORGE BARCLAY BRUCE, President,
in the Chair.

The discussion upon the Paper by Dr. Edward Hopkinson on
"Electrical Tramways: the Bessbrook and Newry Tramway,"
occupied both evenings.

SECT. II.—OTHER SELECTED PAPERS.

(Paper No. 2267.)

“Tacheometry, or Rapid Surveying.”

By BENNETT HOOPER BROUGH, Instructor in Mine-Surveying at the Royal School of Mines.

OF all the operations surveyors are called upon to perform, chaining is without doubt the most tedious and the most liable to error. Measurements are often very imperfectly effected by the chainmen, and more error is made than is usually supposed. In fact, only in rare cases and under favourable conditions can 1 mile be chained to within $\frac{1}{1,000}$ of a second chaining. Methods of surveying in which the distances are measured by the chain are now giving place to a method termed *tacheometry* (*ταχέως*, with rapidity, *μετρέω*, I measure) by its inventor, and *tachymetry* by some other writers. In this the distances are measured indirectly by means of the telescope.

The aim of tacheometry is to survey and level simultaneously a tract of ground with the greatest possible accuracy in the least possible time. For the railway engineer, especially in mountainous districts, it is a method of the greatest value, since it dispenses with the chain and the spirit-level, and thus the laborious, slow, and expensive processes of chaining over bad ground, and of levelling up and down hill, are avoided.

The object of the Paper is to point out the advantages of this method of surveying for certain descriptions of work. The information given is based upon experience gained on the Continent and in America. No details are available of any application of the method in Great Britain, for although the best tacheometers are manufactured in London and largely exported, unfortunately no progress is being made in this country in respect to this important branch of surveying.

Tacheometry was first adopted in Italy in 1823, and since that date has afforded satisfactory proofs of its capabilities for use in surveys of railways, roads, canals, and mines, as well as for topographical and military purposes.

The method consists in obtaining, in a minimum of time, by means of a single observation, the elements determining the

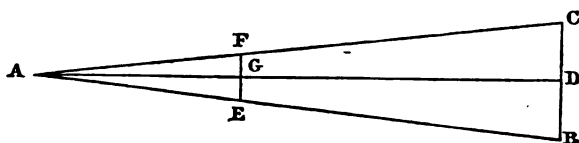
position of every point visible and accessible from a given station point. These elements are, the distance, azimuth, and height. The necessary trigonometrical equations are solved, and all the points are either referred to a system of rectangular co-ordinates, or, when a contoured plan is required, expressed as horizontal distance, azimuth, and relative or absolute height with reference to the centre of the instrument. In this way all the instruments otherwise required—the chain, plane-table, cross-head, offset staves, rods, and levelling instrument—are dispensed with. The number of assistants and workmen is considerably lessened, and the whole responsibility rests on the engineer, on whose skill and discernment the value of the work will depend.

By this method surveys are made in one-third to one-fifth of the time that is required for the older methods. Thus, Mr. Loir finds by experience that to survey and level an area 3 miles long and $1\frac{1}{2}$ mile wide, an observer with the tacheometer and one staff-holder will finish the plan in ten days, whilst with direct measurements of the distance one observer would take at least three months to obtain the same result.

THEORY OF TELESCOPIC MEASUREMENTS.

The indirect measurement of distances by means of the telescope is based on the solution of a triangle (Fig. 1):—

FIG. 1.



Suppose the instrument to be at A and a graduated staff at BC; then the length AD will be known, if the angle DAC and the height DC are known. Two classes of instruments are employed. In one, the angle DAC is constant, and the height of the staff DC varies with the distance. In the other, the height of the staff is constant, and the angle DAC variable.

The typical instrument of the latter class is that of Stampfer. This consists of a telescope that may be moved 8° in a vertical direction. Two divisions on a staff, held at a distance, are sighted successively. These embrace a constant height s . By means of a micrometer screw it is easy to determine the angle through which the telescope has moved in passing from one division to the other. Let α represent this angle, which is equal to the number of turns

n of the screw multiplied by a constant c . The angle being small, it may be assumed that $\tan \alpha = cn$. The distance required will then be equal to $\frac{s}{\tan \alpha}$ or $\frac{s}{cn}$. The constant c is determined by observations along a known distance, and tables are constructed giving the distance for any number of turns given to the screw.

The same principle is applied in Eckhold's omnimeter, an instrument used for revenue surveys in India and for railway surveys in America.

Instruments in which the angle is constant, and the height of the staff variable, are more important and more numerous. The original instrument of this class is the stadia, invented by William Green in 1778. The instrument used in conjunction with the stadia or staff consisted of a tube provided with three parallel wires. In Fig. 1, let G, E, and F represent these wires; G being the axial wire, and E and F the end wires; then the constant angle α will be determined by the height GF, or i , and the distance AG, or r , from the eye-piece to the wires. If AD, the distance to be measured, is represented by d , and if s represents the height of the staff DC, intercepted by the wires G and F, the equation obtained is

$$d = \frac{r}{i} s.$$

The stadia is no longer employed in this primitive form. In Austria, however, a similar instrument is occasionally used in levelling for railway sections. In this the tube is replaced by a pair of sight-vanes, one of which has two parallel wires 0.03 metre apart, stretched across the aperture. The distance from one sight to the other being 0.3 metre, the ratio $\frac{r}{i}$ is equal to 10,

so that, in order to measure distances in metres with this instrument, it is merely necessary to use a staff divided into decimetres.

As a rule, the distances to be measured are so great that a telescope has to be employed; in which case the formula is

$$d = \frac{r}{i} s, \text{ as with the stadia tube; } r, \text{ however, is not constant, but}$$

varies according to the proportion $\frac{1}{r} + \frac{1}{d} = \frac{1}{f}$; f being the focal length of the objective lens.

In the telescopes used in surveying, f is equal to 12 to 15 inches, and r varies as much as 0.24 inch for distances of 20 to 700 yards. Thus, for distances of 100 yards, the variation of r in proportion to the focal length is very slight. It must, however, be taken into account, because r is used as a multiplier.

Different methods are employed for remedying the variability of r . The telescope may be employed like the old stadia-tube; the staff being graduated for a single distance, and no corrections applied when the distance is greater or less than this. This method can be used only when great accuracy is not required.

Early in this century, Reichenbach, a Bavarian engineer, proposed a method that is still in frequent use. He eliminated r in the equations $\frac{1}{r} + \frac{1}{d} = \frac{1}{f}$, and $d = \frac{r}{i} s$, obtaining $d = \frac{f}{i} s + f$. The value d , it is seen, is composed of two terms, one being proportional to s and the other being the focal length f . The distance measured from a point as far in front of the object-glass as the focal length of that lens, is thus proportional to s . Then, if the distance is to be reckoned from the centre of the instrument, a constant, c , the distance from the centre of the instrument to the object-glass, must be added. This may be made by the instrument maker equal to $0.5 f$. The formula is then

$$d = \frac{f}{i} s + f + c.$$

All distances will thus be reckoned from the centre of the instrument, if the sum of the focal length and the distance from the object-glass to the centre of the axis of the telescope is added to the reading at every sight. For example, if the object-glass has a focal length of 6 inches, and the micrometer wires are 6 inches from the object-glass, 1 foot is the constant to be added to each reading.

A staff may be graduated to read the distance direct. It is, however, useful only for measuring distances, and not for levelling at the same time. It is preferable to use an ordinary levelling-staff and a telescope, in which the instrument maker has selected for $\frac{f}{i}$

some multiple of 100. Suppose, for example, that $\frac{f}{i} = 100$. The distance from the centre of the instrument would then be $100 s +$ the constant. The calculation of distances is thus greatly facilitated.

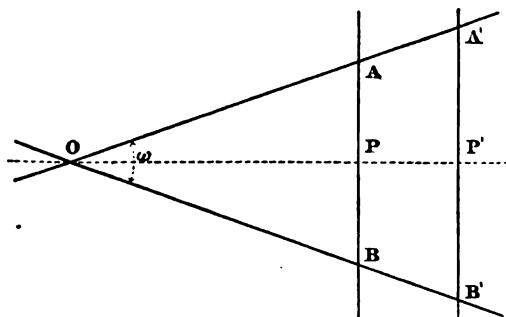
When the line of sight is inclined towards the staff, the space intercepted is increased in the ratio of 1 to the cosine of the angle with the horizon. Thus, the space s' for the staff perpendicular to the horizon becomes s for the staff when vertical, and, by approximation, $s' = s \cos \alpha$. The inclined distance is then equal to $100 s \cos \alpha + (f + c)$, and the horizontal distance is equal to $100 s \cos^2$

$a + (f + c) \cos a$. But since $(f + c)$ is, at most, equal to 2 feet, and the angle a is so very small, c' may be taken as equal to its horizontal projection. The horizontal distance will then be equal to $100 s \cos^2 a + (f + c)$.

In Germany it is usual to hold the staff perpendicular to the line of sight. The inclined distance is then equal to $100 s + (f + c)$, and its horizontal projection is equal to $\{100 s + (f + c)\} \cos a$, or approximately, $100 s \cos a + (f + c)$.

The most effectual method of remedying the variability of r is that proposed by Porro, a Piedmontese officer, afterwards professor at Milan, who in 1823 modified the construction of the telescope in such a way as to remove all necessity for adding constants, and the distances measured from the centre of the instrument are then directly proportional to s . He introduced between the object-glass and eye-piece a third lens, the focus of which coincided with

FIG. 2.



that of the object-glass. Consequently the rays after passing through this third lens become parallel, whilst the sizes of objects subtending the same angle at the centre of "anallatism," or unchangeableness, are proportional to their distance from that point. This point being placed in the vertical axis of the instrument, the telescope is rendered anallatic. In other words, in consequence of the interposition of the anallatic lens, the rays coming from the end-wires to the staff, form an angle ω with its vertex at O, the centre of the telescope (Fig. 2). The angle ω is termed the diastimometric angle, and O the anallatic point. The angle ω varies with the distance of the anallatic lens from the object-glass. If this distance increases, ω decreases, and conversely, whilst if the distance remains constant, ω is invariable. It can easily be seen that the distance from O, the centre of the telescope, can be deduced from the length AB intercepted by the wires. In fact the sides of the diastimo-

metric angle form with the staff virtual triangles OAB , $O'A'B'$. These triangles being similar give :

$$\frac{OP}{AB} = \frac{OP'}{A'B'} = k.$$

It is thus merely necessary to determine a simple constant, the diastimometric ratio, and then to move the anallatic lens until ω corresponds to it. As a rule, k is taken as $\frac{1}{\pi 100}$, in which case ω is equal to 0.32 centesimal degree. It follows that at 200 yards, for example, the length of staff intercepted should be 1 yard. The diastimometric ratio is represented by the expression $2 \tan \frac{\omega}{2}$. The distance is then $s \div 2 \tan \frac{\omega}{2}$.

The original instruments made by Porro were very favourably reported on by the Paris Academy of Sciences and by a French Government Commission. Their extremely delicate nature, however, prevented them from coming into general use.

In 1856, Mr. Moinot, engineer to the Paris, Lyons, and Mediterranean Railway, gave the instrument a form resembling that of the larger modern theodolites. This instrument is based on the same principle as that of Porro, but is much less delicate and less expensive, while giving results of great accuracy. Like Porro's original instrument, Moinot's tacheometer permits distances to be measured at the same time as angles and differences in level. Its use has led to a new method of surveying for railway purposes, which is quite as accurate as the older method of longitudinal and cross sections. By the advantages it presents of greater rapidity, and the small number of assistants required, this method has undoubtedly contributed to the development of railways, notably in mountainous districts. Since its first application by Moinot in 1856, on the line from Nice to Genoa, it has been employed in most of the continental countries, excepting perhaps North Germany. There Reichenbach's method is still used; instruments being constructed under the name of tacheometers, more or less similar to Moinot's tacheometer, but without the anallatic telescope.

The tacheometer is so constructed that $2 \tan \frac{\omega}{2}$ is equal to $\frac{1}{\pi 100}$. The distance being equal to 200 s may be read direct from the staff, if the latter is graduated in half-centimetres. Thus, if the lower wire coincides with the division marked 100, and the upper one with the division 110, the height s will be equal to $110 - 100 = 10$ half-centimetres, and the distance will be 10 metres.

In order to reduce the measured distance to the horizontal, the work is always carried on with the staff held vertical, and the angle of inclination of the optic axis is determined.

CALCULATIONS.

For calculating the results of a tacheometer-survey, the slide-rule may advantageously be used. The logarithmic scale simplifies the tedious multiplications of lengths by tangents and sines. The rule contains scales of numbers, sines, and tangents. To these Moinot has added a scale giving the values of $\sin^2$, the origin of which is so placed that a single setting of the slide gives simultaneously the horizontal distance ($s \sin^2 \phi$), and the difference of level. By means of these scales, the co-ordinates of points observed from a single station with the tacheometer are rapidly computed, without any direct measurements being made.

PROTRACTOR.

The protractor designed by Moinot for plotting tacheometer-surveys differs from the ordinary protractor, in that it gives at the same time the direction and the distance of the point to be determined on the plan. It is a semi-circular protractor, of transparent horn, or of thick paper, provided with a needle-pointed pivot at its centre. Its straight-edge is graduated so that distances can be measured off each way from the centre. Angles are obtained from the graduated semicircle, reading from a point marked on the plan.

THE INSTRUMENTS.

The tacheometer is nothing more than a theodolite with a concentric distance-measuring telescope. It differs from the theodolite in being furnished with an anallatic lens, and usually in being graduated according to the centesimal method, the circle being divided into 400 parts or degrees. Though not indispensable for a tacheometer, this division is very convenient. The angles are read more rapidly, on account of the simplicity of the division into tens and hundreds, and since they are read from two verniers, one at each end of a diameter of the circle, errors are at once evident, the readings differing by 200° . Lastly, with the centesimal division, the slide-rule computations are greatly facili-

tated. Tables of logarithms for the centesimal method have been prepared by Callet, Borda, Plausolles, Laland, and others, and have been in use for many years.

The tacheometer made by Messrs. Troughton and Simms¹ is simple in construction, easy to read, strong, easily manipulated, and may be rectified in all its parts. It differs but slightly from the theodolites by the same makers. The horizontal and vertical circles are divided into 800 parts, each representing half a centesimal degree; and, with the aid of verniers, they can be read to one centesimal minute. The telescope is anallatic, and is provided with a Ramsden eye-piece magnifying thirty times. This can be moved by means of a screw, so as to be opposite to either of the end micrometer wires. The reticule consists of three horizontal wires, the two end ones determining the diastimometric angle, for which the constant $2 \tan \frac{\omega}{2}$ is 0.02.

There are also two vertical wires to test the verticality of the staff, and two diagonal wires fixing the line of collimation.

If the spaces on the staff intercepted by the horizontal wires are represented by the letters a, c, b , the differences $a - c$, and $c - b$ should be equal if the reading has been satisfactorily performed. The distance expressed in metres is found from the following equation:—

$$\text{distance} = \frac{a - b}{0.02} \times \frac{n}{100}$$

in which n represents the number of centimetres contained by the unit of the divisions on the staff.

The tacheometers made by Richer, of Paris, are very similar to those of Messrs. Troughton and Simms. In the newer instruments, however, lines engraved on one of the lenses of the eye-piece are substituted for micrometer wires. Temperature thus has no effect on the micrometer, and there is no danger of the fracture of the wires. The compass is of the tubular type,² and is fixed to the axis of the instrument underneath the horizontal circle. The constant $2 \tan \frac{\omega}{2}$ for this instrument is 0.005.

The Italian instruments made from Porro's designs differ entirely from the English and French tacheometers. Instead of

¹ Drawings of this instrument are given in the treatises of Cavani, Finardi, and Carderera.

² Minutes of Proceedings Inst. C.E. vol. lxxxvi. p. 459.

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being made so that they can be tested and rectified in all their parts, they are constructed with great care, and accurately adjusted before leaving the workshop, so that when once in position they can be used without any delay. They must, of course, be tested by the maker from time to time. The typical instrument of this class is the *cleps-circle* or *cleps*.

The principal differences in construction between the tacheometer and the cleps are the following:—The tacheometer has its horizontal and vertical circles uncovered, as in the ordinary transit-theodolite, whilst in the cleps they are enclosed within a cubical box. With the tacheometer, the angles are read by means of verniers; in the cleps they are read by means of micrometer wires applied to microscopes. The tacheometer telescope is concentric; that of the cleps is eccentric. The graduation of the circles of the tacheometer proceeds in the direction of the movement of the hands of a watch, whilst the circles of the cleps are graduated in the opposite direction. The tacheometer telescope is provided with an ordinary Ramsden eye-piece; that of the cleps has a multiple eye-piece of the Argo type. Both instruments are furnished with anallatic lenses, and the circles are graduated according to the centesimal method.

The cleps, as originally constructed by Porro, is provided with a telescope magnifying eighty times. In order to detect errors in reading the staff, and to help in cases where readings are obscured by obstructions, seven parallel horizontal wires are supplied. There is also one vertical wire. Three movable lenses are used for reading the different groups of wires, according to the distance. And, in order to facilitate the reading, staves with different graduations are employed. Porro's staff consists of a triangular prism, with a different graduation on each face. The compass is of the tubular type, the magnetic needle being suspended by a silk fibre. With this instrument Porro attained such accuracy in the measurements of distances, that the error never exceeded $\frac{1}{2,000}$.

These instruments are still made by the firm of Salmoiraghi and Co. of Milan, who have, since 1873, when they succeeded to the works of Porro, sold more than three hundred. Of these several were manufactured for Spain, Mexico, the Argentine Republic, Brazil, France, Greece, and Bulgaria, whilst a large proportion was purchased by Italian engineers. The cleps was used with considerable success in the surveys for the Mont Cenis tunnel.

Besides necessitating very careful manipulation, these instruments have the undoubted disadvantage, that it is impossible for the engineer to test the accuracy of the details of construction.

The eccentric position of the telescope, even though the eccentricity in the largest instruments is not more than 3 inches, must also be regarded as undesirable.

THE STAFF.

The staves used in tacheometry are always graduated with sufficient distinctness to be read by the observers. Porro's staff is triangular in section, and has three graduations with different subdivisions according to requirements. For short distances, the divisions are extremely fine; for greater distances only whole metres are marked in bold figures. Moinot's staff is graduated in such a way that it can be used for short or for long distances.

The staff should not exceed 12 to 16 feet in length, and should be made of light wood. During the observation it must be held perfectly vertical. It should therefore be provided with a plumb-line, or, better, with a round spirit-level, the tangential plane of which is perpendicular to the graduation of the staff.

The error caused by reading the micrometer wires when the staff is inclined is very considerable. Thus, with a horizontal line of sight ($\phi = 90^\circ$), the staff must not deviate more than $3^\circ 40'$ from the vertical, to keep the error of reading below $\frac{1}{300}$, or 0.002;

$\phi = 90^\circ$ limit of error, 0.002; maximum angle $3^\circ 40'$.

$\phi = 60^\circ$ " 0.002; " $0^\circ 12'$.

$\phi = 45^\circ$ " 0.002; " $0^\circ 6'$.

Conversely, assuming that the staff is held within 1° of the correct vertical position, the errors in reading resulting from this position will be as follow:—

$\alpha = 1^\circ$ constant.

$\phi = 90^\circ$, resulting error 0.015 per cent.

$\phi = 80^\circ$ " 0.29 "

$\phi = 70^\circ$ " 0.62 "

$\phi = 60^\circ$ " 1.00 "

$\phi = 50^\circ$ " 1.44 "

$\phi = 45^\circ$ " 1.73 "

It is advisable to use the lower portion of the staff more frequently than the upper, because the error in reading is reduced by the vibrations of the staff not being so perceptible. The results given above show that it is much better to work at a distance, if the angles of elevation and depression are thereby

lessened, that is to say, if ϕ approaches a right-angle, than to work close to the staff, and be compelled to employ considerable deviations from the horizontal, since the error increases not only in proportion to a , but also very rapidly in proportion to ϕ .

With reference to reading the staff itself, it is of great advantage to use as few figures as possible for reading, writing, and calculating. It is therefore advisable to direct the lower wire to a round number (metre). It would, of course, be best to place the lower wire at zero, as Porro expressly desired; but it is obvious that this can very rarely be done in practice.

THE FIELD-WORK.

Tacheometric surveys are usually conducted by a party of three, (1) the engineer to direct the work; (2) the observer at the instrument; and (3) the recorder to book the results. On level ground two staff-holders are employed, and on irregular ground one or two in addition, in order to prevent loss of time to the observer. For less important surveys one observer and one staff-holder suffice.

When the instrument has been set up at a suitable site, staff-holders are sent to all the points to be surveyed. To each point a number is assigned, and noted in the field-book, and on a sketch made at the same time. If the survey is for topographical purposes, it is advisable to follow as closely as possible the boundaries of the fields. The telescope is directed towards the staff, and the micrometer wires are read and noted in the proper column of the field-book. The horizontal and vertical angles are then read and noted. This operation is repeated for all the points that can be seen from this station.

In this way, for every point three figures are obtained—the distance, and the horizontal and vertical angles. The point is thus fixed by means of polar co-ordinates.

If the survey has to be connected with one previously made, some data from the former work are necessary in order to make the connection. Two points, if accurately determined, are sufficient.

The instrument having been set up and levelled, the engineer makes a reconnaissance of the ground to be surveyed, and gives instructions to the staff-holder, who goes successively to all the points selected by the engineer, and at each one holds the staff steadily vertical until he receives a signal to pass on. The observer at the instrument now makes the necessary observations, which are noted in the field-book by the recorder.

When the ground to be surveyed is so extensive that two stations are necessary, the engineer selects two points visible from both stations. When the observation at the first station is finished, the instrument is moved to the second, and the two points are observed. The connection could, of course, be made by one point only. It is, however, advisable to employ two as a check on the accuracy of the work. When a number of stations are required the method is similar. The method described is that used by Porro.

Moinot employs the tacheometer in preliminary surveys for railway lines in the following manner: Before the belt of ground is surveyed an extensive reconnaissance is undertaken, and the main direction of the railway determined, so that the survey may be limited to a comparatively narrow strip. On account of the rapidity of the method there is no occasion to be too anxious about limiting the width. A strip should always be selected of sufficient width to allow if necessary a lateral displacement of the line. A width of 400 yards is quite sufficient. Marks are fixed 200 to 300 yards apart, and numbers are assigned to them. For filling in details, points are chosen wherever the ground presents any decided change of level. The instrument is set up at a point so selected that connection can be made with any existing survey or railway. The assistant then gives a signal with a whistle or horn to announce that he is ready. In the meantime the recorder has measured and noted the height of the instrument, and the engineer has made a sketch roughly to the scale of the plan to be prepared, showing all the roads, rivers, boundaries, fields, and the station of the instrument. As soon as he hears the signal, the engineer indicates to each staff-holder his place, care being taken that only one staff is ready at a time. The other staff-holder is still on the road, or if already at his post he turns the narrow side of the staff towards the instrument, and remains in this position until it is signalled to him that the preceding reading is finished. He then turns the graduation of the staff towards the instrument, and by a signal directs attention to his position. He next awaits the signal that he can pass on.

The assistant at the instrument has to read the upper and the lower wires with each staff, and then the vertical and horizontal angles, and to call them out in this order to the recorder, who notes them in the field-book. The recorder enters the points in order, as 1, 2, 3, &c. At every fifth or tenth point the assistant gives a double signal, whereby the engineer, although at a distance from the instrument, has a check on the accuracy of the booking.

seeing that he has entered the points in his sketch in the same order.

To economize time, the engineer selects the points in such a way that he comes finally in proximity to the point he regarded as being most suitable for the next station. Here he places a mark and sets up a staff, at the same time giving a special signal to the assistant.

When the readings for this next station are finished, the observations at the first station are complete, and the instrument is carried on. In the meantime, the man who was holding the staff at the new station returns to the preceding one just left by the instrument. The recorder begins a new station in the field-book, and at once enters the height of the instrument in its proper column. A back observation is now taken, and the distance, height, and azimuth, should coincide with the results previously obtained.

If the instrument employed is not provided with a compass, the utmost care must be exercised in reading the horizontal angle, since an error in this is not easily detected.

On comparing Moinot's method with that of Porro, it will be seen that the latter is capable of more general application. It necessitates, however, the use of a compass instrument. The principal difference in the two methods is in the selection of the station points. The advantage of Porro's method is that the choice is almost unlimited. The stations, too, may be further apart. An additional advantage is that the point where the instrument is set up is the correct station point, and consequently no time is wasted in exactly centering the instrument over a given point, always a difficult operation on irregular ground. In favour of Moinot's method, on the other hand, may be urged the facility with which the operations may be checked in the field.

FIELD-BOOK.

The record of the survey in the note-book occupies the right- and left-hand pages. Fifteen columns are ruled. The number of the station is inserted in the first column. The second column gives the height of the line of collimation above the point levelled. The third column contains the numbers of the points selected. The fourth and fifth columns contain the horizontal and vertical angles observed. The sixth column contains the reading of the micrometer wires, their difference being inserted in the seventh column. The eighth column contains the height of the line of

collimation on the staff, obtained by reading the axial wire. The remaining columns (nine to fourteen) are reserved for the calculated results, whilst in the fifteenth column are inserted any remarks of value in preparing the plan or section.

The method of booking will be seen from the two examples given in Appendix I.

As a guide in plotting the survey, a pencil sketch of the ground should be made. The side readings are plotted by the protractor, whilst the station points are plotted by rectangular co-ordinates. A plan is thus constructed on which contour lines may be traced, and by calculation the direction of a projected railway, road, or canal, may be determined.

By this method, Moinot has surveyed about 1,000 miles for railway purposes. The distances when measured on the ground with extreme care have never differed from those shown on the plan by more than 1 per 1,000, and the longitudinal section obtained by accurate spirit-levelling has never presented any appreciable difference when compared with the results afforded by the heights given on the plan.

The maximum error likely to arise in reading the difference between the micrometer wires is 0.1 inch in a distance of 100 yards. On horizontal ground this would represent an error in the distance of 18 inches. Plotted on a scale of 1 : 2,000, this error would be 0.009 inch on the plan. For distances which have to be reduced to the horizontal, the error would be less. For preliminary surveys for railways a greater degree of accuracy is unnecessary.

THE TOPOGRAPHICAL STADIA.

The topographical stadia differs from the tacheometer in that the micrometer is not applied to the telescope of a theodolite, but to the alidade of a plane-table. The points are observed from one station, the distances from this being reduced to the horizontal, and the heights calculated on the spot by means of a special slide-rule. The data thus obtained are at once plotted to the scale required on a sheet of paper stretched on the plane-table, the height of each point being accurately noted. When the height of a sufficient number of points has been determined, contour lines are traced with the ground in view. In fact, the ground is practically sketched from nature.

This method was first used by the officers engaged on the survey of Geneva in 1838. It was subsequently improved by Professor J. Wild, of Zurich, who employed it on the Swiss survey in 1843

to 1851. Since 1855, Professor Wild has instructed his pupils, at the Polytechnic School of Zurich, in its use, and every engineer trained at that institution during the last thirty years has been made acquainted with the method. This has largely helped to extend its use. All the Swiss railways made during the last fifteen years, and notably the St. Gothard and Simplon lines, have been constructed from plans prepared in this way.

The plane-table in its ordinary form is not well adapted for surveying in conjunction with the stadia, and three forms of plane-table are specially made for the purpose by J. Kern, of Aarau. The alidade of the plane-table of the largest size used is provided with a transit-circle $6\frac{1}{2}$ inches in diameter, a telescope $11\frac{1}{2}$ inches long, and a ruler $21\frac{1}{4}$ inches long. This instrument, with all its accessories, including the slide-rule and graduated staff, costs 594 francs.

A series of experiments, made by Mr. Stambach in 1879, to determine the accuracy of measurements with the stadia, gave the following results:—The total difference between the measured and the observed distances of eighteen lines, varying in length from 67 to 14 metres, was 1 metre. The total difference in twenty-five lines, varying from 6 to 60 metres in length, was 1.38 metre. The mean error for each line is therefore $238 \div 43 = 55$ centimetres, and the greatest possible error for each line is 8 centimetres (3.15 inches). The errors, it may be noted, do not increase absolutely in proportion to the distance, and they are as apt to be plus as minus.

With telescopes of higher power, still greater accuracy is obtained. Thus, for twenty-eight lines, varying from 4 to 68 metres in length, measured and observed in 1883, the sum of the differences is 130 centimetres, giving a mean error of 4.6 centimetres (1.8 inch).

The distance up to which the divisions on the staff may be read with perfect security depends on the magnifying power of the telescope. As a rule, the telescopes attached to plane-tables magnify twenty times. A staff clearly graduated in black may be read with a telescope of this power at a distance of 300 metres (985 feet). In exceptional cases, when the atmosphere is clear and steady, points may with care be determined, with a considerable degree of accuracy, at a distance of 500 metres (1,645 feet). It is, however, advisable not to exceed 200 to 250 metres.

With a constant of $k = \frac{1}{100}$ the error for a horizontal sight would not exceed $\frac{1}{100}$ of the distance. The most advantageous distances are those between 30 and 120 metres, when, with telescopes

magnifying twenty-five to thirty times, fractions can be accurately read on the staff to 1 millimetre.

In surveying with the topographical stadia, care must be taken in the selection of station points, with a view to accelerating the work, since from each station as many points as possible are taken. Each of these points necessitates the following operations:—1. Sighting with the instrument and reading the staff; 2. Reading the vertical circle; 3. Calculation of the horizontal distance, and the difference of level by the slide-rule; 4. Plotting the distance by the scale attached to the plane-table, thus fixing the position of the point; 5. Noting the height of this point above the datum line.

It is remarkable with what rapidity these operations may be performed. An observer accustomed to the work can easily survey and plot on the plane-table forty points an hour. According to the irregularity of the ground, it will be required to survey 1,200 to 2,000 points per square kilometre. This represents three to four days' work, reckoning ten hours a day. The rapidity attained with this instrument is greater than that with the tachometer, and the cost of the survey is less. The determination of the vertical angle, the reading of the staff, and the slide-rule calculations, occupy the same time with both instruments. But the observation and noting of the horizontal angle with the tachometer requires twice as much time as the simple sighting with the telescope, and the fixing of the point on the plane-table.

The cost of the small-scale topographical map of Switzerland prepared from surveys by this method, under the direction of Colonel Siegfried, was:—

	Square League.	Square Mile.
	Francs.	£. s. d.
1. Scale 1 : 25,000, easy ground	800	3 12 0
Scale 1 : 25,000, difficult ground	850	3 16 6
2. Scale 1 : 50,000, in all cases	450	2 0 5

The cost is calculated per square league (the Swiss league = 2·98 miles).

In the surveys for the Simplon tunnel, made in 1882, the cost of the preliminary triangulation, setting out the line of operation, and connecting it with the triangulation and the levelling of the bench-marks, amounted to £25 to £30 per square mile. The survey and plotting to a scale of 1 : 5,000 cost £50 to £70 per square mile. The ground was as a rule very difficult and uneven. The number of points surveyed varied from five to twelve per acre. All the operations together cost £75 to £100 per square mile. It must be taken into account that a large portion of the work was done

in winter, the length of the working day averaging nine hours. In summer, with twelve working hours, a reduction of 25 per cent. may be allowed. The cost would then be £55 to £75 per square mile.

On the United States Coast and Geodetic Survey, the plane-table has been exclusively used for making topographical surveys; the stadia, or telemeter as it is called on that service, being used in connection with it. The stadia is graduated experimentally for the particular instrument, and for the eye of the observer who has it in use. It is simply a scale of equal parts painted upon a wooden staff, about 10 feet long, 5 inches wide, and $1\frac{1}{4}$ inch thick, so graduated that the number of divisions, as seen between the horizontal wires of the telescope, is equal to the number of metres in the distance between the observer's eye and the staff held at right-angles to the line of sight.

American experience tends to show that the plane-table is adapted to open country and long distances, where no contour lines are to be determined, and where the stations are comparatively few, as well as where a multiplicity of detail is required. Against the advantage of plotting the work in the field may be placed the disadvantages of having no record but the field-sheet, which is liable to be spoiled in a storm.

THE THEODOLITE AND STADIA.

The method of surveying with the plane-table and stadia is being superseded in America by the use of the transit theodolite and stadia,¹ a method introduced in 1864, when it was officially adopted on the United States Lake Survey. All that can be done with the plane-table may also be done with the transit theodolite. The plane-table can be used only for topographical work, and requires special practice, whilst the theodolite for a stadia survey can be adopted in all cases where a theodolite is required, and but little special training is required in order to use it with the stadia.

The best instrument to employ is a theodolite reading to 30". The micrometer wires should be fixed; when adjustable, they are not sufficiently stable to be trustworthy. The stadia is usually a staff 1 inch thick, 5 inches wide, and 14 feet long. In order to graduate the staff, it is necessary to know what space on

¹ See "A Manual of the Theory and Practice of Topographical Surveying by means of the Transit and Stadia." By J. B. Johnson, 113 pp., New York, 1885.

it corresponds to 100 feet (or yards, or metres) in distance. To determine this, it is best to measure off $c + f$ in front of the plumb-line, and set a point. From this point, accurately measure a base line of (say) 200 yards, on level ground, and hold the blank staff at the end of this line. Have a fixed mark on the upper portion of the staff, and set the upper wire on this. Then let an assistant at the staff record the position of the lower wire, as he is directed by the observer at the instrument. Repeat the operation until the mean gives a satisfactory result. If the base was 200 yards long, divide the space intercepted by the two wires into two equal parts, then each of these parts into ten smaller parts, and finally each small space into five equal parts. One of these last divisions will represent 2 yards. Diagrams are then to be constructed on this scale, in such a way that the number of symbols can be readily estimated at the greatest distance at which the staff is to be held. If, when tested by re-measuring the base-line, the wire interval is found to have changed, the staff must be re-graduated, or a correction must be made to all the readings. If the wires are adjustable, any unit scale may be selected, and the wires adjusted to this. By this method, distances may be obtained from levelling-staves, where it is desirable that each foot on the staff should correspond to 100 feet in distance.

In making a survey for the purpose of preparing a contoured plan, a series of points should be determined with reference to each other, both in geographical position and in elevation. These points should not be more than 3 miles apart. The points of elevation, or bench-marks, need not be identical with the points fixed in geographical position. The latter are best determined by triangulation.

A system of triangulation points being established, the angles are observed and the stations plotted on the plan. For small areas the plotting is best done by means of rectangular co-ordinates. The survey may, however, be plotted directly from the polar co-ordinates (azimuth and distance). For this purpose the plan should have printed upon it a protractor circle, 12 inches in diameter, by means of which the lines can be plotted accurately to 5'.

A line of levels is next run, bench-marks being left at convenient points. The topographical survey is then made, and referred to this system of triangulation points and bench-marks. The surveying party should consist of the observer, a recorder, three staff-holders, and, if necessary, two axe-men.

The record in the field-book consists of (1) a description of the point; (2) the reading of the vernier; (3) the distance; (4) the

vertical angle. Two columns are left for reduction; (5) the difference of height corresponding to the given vertical angle and distance; (6) the true height of each point above the datum line. The right-hand page of the field-book is reserved for sketching.

The only calculations necessary are to find the height of all the points taken, with reference to the datum line, and sometimes to correct the distance read on the staff for inclined sights. These calculations may be performed by means of tables computed by Mr. A. Winslow, of the State Geological Survey of Pennsylvania, or by means of a diagram prepared by Professor J. B. Johnson, of Washington University. This diagram¹ is printed on thick paper, 20 by 24 inches, and is so arranged as to give distances to 500 yards or metres, or 1,500 feet, with elevations to 50 feet. Heights are read on the diagram to the nearest tenth of a foot, with great facility.

The only available information as to the accuracy of this method of surveying is given in the report of the United States Lake Survey for 1875. The entire stadia work of that year was co-ordinated, and compared with the corresponding distances obtained by triangulation. In this way one hundred and forty-one lines, on an average $1\frac{1}{2}$ mile in length, were tested, the average error being 1 in 650. The length of sight between the stations averaged 800 to 1,000 feet. The limit of error allowable in closing on a triangulation was 1 in 300. No special pains were taken to make these lines more accurate than others, since it was not known at the time that the results were to be tested. The readings were taken to the nearest metre; the staves were graduated for a single distance; and no corrections were applied when the distance read was greater or less than this. The accuracy thus attained was sufficient for the object of the survey. Had more care been exercised in the work, the readings limited to 1,000 feet, and all corrections applied, it would have been easy to bring the error within 1 in 1,200.

With reference to the cost of this method, there is but little available information. The Reports of the Mississippi River Commission furnish some evidence. The survey of that river has been completed from Cairo to Donaldsville, a distance of 885 miles, during the last five years. The survey includes a belt of ground on each side of the river, from 1 mile to $1\frac{1}{2}$ mile in width, making in all some 2,500 square miles of topography. The cost per square mile of the survey of the whole belt, including the river and its

¹ Published by J. Wiley and Sons, New York. Price 50 cents.

surroundings, was £12. The cost of the topography alone should be placed at £15 per square mile. In this work the contours are 5 feet apart, and a large portion of the district is thickly wooded. The surface is very irregular, and a permanent bench-mark was set up at every square mile, the cost of which is included in the above estimate. The cost of making pencil field-plots to a scale of 1 : 10,000 is also included. If the elevations and contours were not desired, the cost would be reduced by more than 50 per cent. And in open country the reduction would be very much greater.

The cost of a survey of the gold-field on the coast of Nova Scotia, extending over 180 square miles, made by Mr. W. B. Dawson,¹ Assoc. M. Inst. C.E., by means of the theodolite and stadia, was £3 11s. 6d. per square mile. Relative elevations were determined in a general way, but no contour lines were drawn.

The cost of a survey of the banks of the Missouri River, made by this method, is estimated at £5 per square mile. In this survey no contour lines were determined.

THE WAGNER-FENNEL TACHEOMETER.

With the instruments usually employed for stadia surveys, it is necessary to calculate the co-ordinates of the points above which the staff is placed. With the instruments constructed by Otto Fennel of Cassel these calculations are not required, the instruments giving graphically at one setting the co-ordinates of the points. By means of the stadia the inclined distance is read, and the elevation and the horizontal distance are read direct from the instrument without calculation.

In stadia surveys, horizontal angles may be read by means of the theodolite, the compass, or the plane-table. Three different forms of the Wagner-Fennel tacheometer are made, in which horizontal angles are measured in these different ways. The characteristic part of the instrument is the projection apparatus (Fig. 3) invented by Wagner, which is identical in them all.

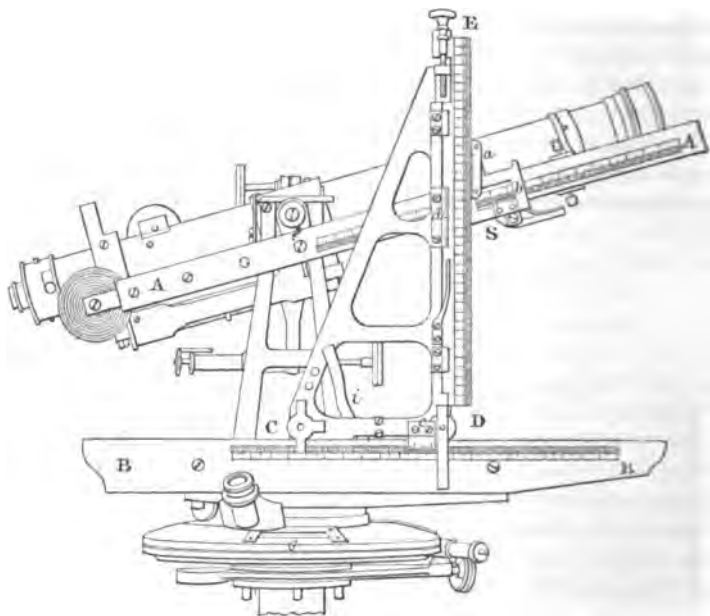
A rule AA provided with a scale of equal parts is fixed by two arms to the telescope of the tacheometer. One of these arms is placed in the axis of the telescope outside the support, whilst the other is near the object-glass. The upper edge of this rule is parallel to the line of collimation; and consequently whatever may be the direction of the telescope, the rule takes exactly the inclination

¹ Minutes of Proceedings Inst. C.E. vol. lxxxii. p. 326.

and direction of the line of sight. A slide *S*, provided with two verniers and an automatic spring, is attached to the rule. The upper vernier *a* is pivoted on an axis, of which the centre is accurately in the edge of the rule, so that it can be placed vertically at any position of the telescope. The lower vernier *b* is parallel to the scale, and serves for exactly reading the oblique lengths.

Almost perpendicularly below the rule described, is fixed a second rule provided with a scale of equal parts. Its plane is

FIG. 3.



parallel to that of the upper rule and its upper edge is horizontal. Along the horizontal edge a rectangular triangle *CDE* slides. Its vertical side is provided with a scale for reading heights. Whatever may be the position of the triangle, this scale of heights will be in the same vertical plane as the upper vernier, so that with this vernier may be read the height of the point sighted above any assumed datum line. By means of a vernier *c* with which the horizontal scale is provided, distances reduced to the horizontal may be read directly.

The tacheometer is made with a 6-inch repeating-circle, divided sexagesimally into thirds of degrees with the vernier reading to

thirty seconds, or centesimally in half degrees with the vernier reading to minutes ($\frac{1}{100}$).

Trials recently made with this instrument by Messrs. Müller and Stiehl, government engineers at Cassel, gave, for points previously measured with the chain and carefully levelled, differences in length not exceeding 20 inches, and differences of elevation not exceeding 2 inches in distances varying from 10 to 300 yards. In a seven days' survey, made in unfavourable winter weather, the positions and heights of three hundred and twenty points were determined per day, all the calculations necessary with other tacheometers being dispensed with.

With this instrument there is the disadvantage that the staff must be held at right-angles to the line of sight. In order to enable the observer at the instrument to see if the staff is held correctly, the rectangular vane sighted is painted black in front, and white above and below. Through the telescope the observer should see only black planes if the staff is held correctly. If, however, the position is incorrect, he will see white bands above or below, the width of which is proportional to the deviation from the correct position.

APPLICATIONS OF TACHEOMETRY.

Besides being well adapted for topographical surveys and for preliminary surveys for railways, the stadia system has been advantageously used for preliminary surveys for canals, dams, reservoirs, and aqueducts. It has also been found the most suitable method for surveys of ditches and pipe-lines in mining-districts and elsewhere, as well as for surveys for bridge-sites, bridge foundations, and all river and harbour work where chaining is difficult. In mining and geological surveys, too, the method has been used with considerable success.

In mine-surveys very accurate readings may be obtained on account of the steadiness of the air. A transit theodolite magnifying ten times, with adjustable micrometer wires, was used in 1865 with great success by Mr. B. S. Lyman,¹ for surveying in an American colliery. It saved much disagreeable groping in the mud to count the links of a chain, and levels were taken at the same time. The wires were placed so far apart that 1 foot of space intercepted on the staff indicated a distance of 100 feet. The figures on the staff were painted with red ink upon thin paper

¹ Journal of the Franklin Institute, vol. lv. 1868, p. 385.

that had been fastened to strips of common window glass by transparent varnish. Then over the paper another coat of varnish was poured, and upon this was placed another strip of glass. The glasses, with the paper between them, were then put into a narrow wooden frame, which formed one side of a long box. This had neither top nor bottom, and its sides were so hinged together that they folded over upon each other when not in use. The back of the box had holes through it to supply air to the lights, and either safety-lamps or candles were fixed to the wood of the back. The box was made 5 feet in length; but for low mines one might be made much shorter. This staff lighted inside makes telescopic measuring and levelling easy underground, where chaining is particularly disagreeable.

Tacheometry is specially adapted for geological surveys, which have frequently to be made in mountainous districts where chaining is laborious and inaccurate, and where levelling up and down the sides of the mountains is not to be thought of. The Geological Survey of Pennsylvania has surveyed some 3,000 square miles by means of the transit theodolite and stadia. In the vicinity of mines and where land is valuable the work is done with extreme accuracy, the length of the lines being limited to 400 feet. The field sketches are prepared with great care, and the time occupied is so great that it is found injudicious to employ more than one staff-holder to a theodolite.

The method might also be advantageously applied to surveys for drainage or irrigation purpose, where contours would afford valuable information. The principal advantage would be the great economy in cost. Thus to survey an area of 75 to 100 acres, one observer and one staff-holder would be sufficient. Assuming that the ground has the form of an irregular polygon, three stations should be selected in it in such positions that from each of them all parts of the polygon can be seen. Two days at most would be required for the survey. A third day would be occupied in plotting it to a scale of 1 : 1,000, and in calculating the area by means of the slide-rule. The remuneration of the engineer and staff-holder amounting together to 24 shillings a day, the preparation of a contoured plan of 100 acres and the calculation of its area would not exceed £4, or 9·6*d.* per acre.

A party of three men, assisted by two staff-holders, under ordinary conditions, survey in a day seven stations, which furnish some six hundred points distributed over an area of 124 to 148 acres. From this it may be deduced that one observer with one staff-holder can survey 74 to 124 acres in two days.

Thus a survey by Moinot occupied the following length of time :—

	Hours.
Field-work, two days of ten hours	20
Calculation of the co-ordinates of forty points	0½
Calculation of six hundred heights above datum	3
Plotting to a scale of 1 : 1,000	3
Inking-in the plan and heights	3
Calculation of the area with the slide-rule	0½
	—
Total for survey and plan of 89 acres	30
	—

Surveys with the stadia, it is thus seen, present considerable advantages as regards rapidity over other methods. Since the survey is made by means of rays from one point, the calculation of areas is greatly simplified, the time occupied by the calculation being shortened by two-thirds. The polygons are divided into triangles, of which two sides and the included angle are known. The area of each triangle being represented by the formula $\frac{1}{2} a b \sin A$, the logarithmic calculations are of the simplest character. The scale of sines and the sliding-scale of numbers are on the same side of the rule, and the calculations are effected in two settings; the first gives the product of the two sides, whilst in the second setting this product is multiplied by the sine of the angle, the area of the triangle being thus obtained. The calculations of the forty-one triangles of the polygon of Moinot's survey were made in half an hour with the slide-rule. Calculations with the tables made for comparison occupied an hour and a half. The results with the slide-rule are of course less accurate; but the error is not of great importance, since it never exceeds $\frac{1}{2,700}$.

In America the stadia method has been applied with considerable success in the survey of drainage-basins for water-supply and sewerage. The survey of some 400 square miles for the new water-supply drainage-basin for the city of Philadelphia, recently completed by Mr. R. Hering, M. Inst. C.E., was made by the transit theodolite and stadia.

The tacheometer being so well adapted for such different uses, it is evident that it deserves to be more generally employed; and there is no doubt that its use would extend, if the simplicity of its construction was better known. Moinot advocates its employment in remaking the French survey, should that important work be executed, and from an experience of thirty-eight years with this method, he is convinced that more accurate results would be obtained at less expense than with the usual methods. The difficult and uncertain setting out and chaining of long lines, often

passing over valuable crops, would be entirely superseded, whilst a new survey and levelling with the stadia would not cost more than spirit-levelling alone. In fact the levelling of a mountainous country is practicable with this method only.

The Paper is accompanied by several diagrams, from which the Figs. in the text have been prepared.

APPENDIX I.—MODEL OF FIELD-BOOK.

A.—Centesimal graduation in 400° ; $k = \frac{1}{16}$; staff divided in half-metres; with horizontal line of sight the vernier reads 100° .

No. of Sta- tion.	Height of Instru- ment.	No. of Point.	Angle Observed		Reading of Wires o s	Difference o - s.	Height of Axial Wire in Metres.	Horizontal Distance $g \sin^2 \phi$.	Height.	Difference		Height above Datum		Remarks.
			Horizontal.	Vertical.						Rise.	Fall.	Of the In- strument.	Of the Point.	
	I.		θ .	ϕ .		g .	m.	D.	h .	$s = t - m$.				
D	1.52	..	o .. , C 137 21	o .. , 101 30	..	..	..	..	..	..	..	213.21	211.69	Previous station.
		C	..	..	3.809 1.000	280.9	1.202	280.8	5.718	..	6.920	..	206.29	
		1	..	105 25	2.483 1.000	148.3	0.871	147.4	12.2	..	13.0	..	200.2	
		2	..	97 50	3.335 2.000	133.5	1.334	133.1	5.2	3.9	..	..	217.1	
		3	..	88 60	3.072 1.000	207.2	1.018	200.8	36.3	35.3	..	..	248.5	
		4	..	110 45	3.114 2.000	111.4	1.278	108.5	17.9	..	19.1	..	194.1	
		5	..	103 10	3.822 1.000	288.2	1.220	287.6	14.0	..	15.2	..	198.0	
		6	..	117 50	1.475 1.000	47.5	0.619	44.6	12.1	..	12.7	..	200.5	Next station.
		7	..	95 75	2.336 1.000	133.6	0.834	133.0	8.9	8.1	..	..	221.3	
		E	..	99 15	3.890 1.000	289.0	1.223	288.9	3.866	2.643	..	..	215.85	

MODEL of FIELD-BOOK.

B.—Sexagesimal graduation in 360° ; with horizontal line of sight the vernier reads 0° ; staff divided in whole metres as unit; $k = 100$.

No. of Station.	Height of Instrument.	Angle Observed		Reading of Wires o u	Difference o - u.	Height of Axial Wire in Metres.	Horizontal Distance $k g \cos^2 a$.	Height.	Difference		Height above Datum		Remarks.
		θ .	a .						Rise.	Fall.	Of the Instrument.	Of the Point.	
	I.				g .	m .	D.	h .	$s = t - m$.				
M	1-23	..	o .. , 340 34 +1 32	.. 4-862 1-000	.. 366-2	.. 2-831	.. 365-9	.. 9-80	.. 6-97	..	244-78	243-55	Previous station.
	a	131 25 +7 15	o .. , 131 25 +7 15	2-144 1-000	114-4	1-572	112-6	14-3	12-7	..	..	257-5	
	b	203 35 +6 30	o .. , 203 35 +6 30	3-215 2-000	121-5	2-608	120-0	13-6	11-0	..	..	255-8	
	c	341 45 -1 25	o .. , 341 45 -1 25	3-883 2-000	188-3	2-942	188-2	4-1	..	7-0	..	237-8	
	d	151 5 +3 45	o .. , 151 5 +3 45	3-510 2-000	151-0	2-755	150-3	9-8	7-0	..	..	251-8	
	e	357 10 -8 35	o .. , 357 10 -8 35	3-299 2-000	128-9	2-645	126-1	19-2	..	21-8	..	223-0	
	f	98 55 +5 5	o .. , 98 55 +5 5	2-180 1-000	118-0	1-590	116-9	10-2	8-6	..	..	253-4	
	N	178 38 -2 17	o .. , 178 38 -2 17	4-851 1-000	385-1	2-926	384-5	15-33	..	18-26	..	226-52	
													Next station.

APPENDIX II.—BIBLIOGRAPHY.

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Copies of these works are deposited in the library of the Institution.

(*Paper No. 2268.*)

“Southampton Sewage-Clarification, and House-Refuse Disposal Works.”

By WILLIAM BENJAMIN GEORGE BENNETT, Assoc. M. Inst. C.E.

THE Author was instructed, by the Corporation of Southampton, to devise a scheme for the clarification of the sewage of a part of the borough, which was discharged into Southampton Water at the Town Quay, and also for the more efficient collection and disposal of the house-refuse of the whole town. He accordingly proposed the adoption of Messrs. Manlove, Alliott, Fryer and Co.'s Refuse Destructor, to serve the double purpose of destroying the ash-bin contents and garbage, and of disposing of the sewage-sludge deposited, in the process of clarification, in two existing reservoirs adapted for the purpose (Plate 2, Figs. 1 and 2). Formerly the sewage of a district of the town, amounting to 500,000 gallons in twenty-four hours, from a population of about thirteen thousand, for the most part flowed by gravitation into these reservoirs, from whence it was discharged into the tideway at low water; whilst a small portion, coming from a low-level sewer, passed through iron pipes A A, laid under the reservoirs, direct into the tideway (Plate 2, Fig. 1). The reservoirs act alternately, one being left still for the precipitation of the sewage, whilst the other is being filled.

In order to render the discharge of the effluent from the reservoirs independent of the tide, and to raise the low-level sewage into the reservoirs for treatment with the rest, two of Shone's pneumatic ejectors were put down (Plate 2, Figs. 3 and 4), one of 360 gallons capacity, B, placed below the invert of the low-level sewer, which serves for discharging the sludge as well as for raising the low-level sewage, and the other of 700 gallons capacity placed in the east reservoir at C (Plate 2, Figs. 1 and 2). In each reservoir there is a floating sewage-inlet, D D, consisting of a pipe connected with the large ejector, and shackled to a buoy which makes the pipe rise and fall with the water-level, keeping its mouth, which is covered with a perforated plate, a few inches below the surface of the effluent, to prevent the passage of any floating matter (Plate 2, Figs. 3 and 4). Directly the clarification by precipitation has been effected to a certain depth, a valve is

opened, admitting the effluent into the ejector C, whence it is at once discharged into the tideway. A supplementary sewage-outlet is also provided in each reservoir for discharging the effluent by gravitation when the tide is low enough. When the whole of the effluent has been thus drawn off, the buoy, resting now upon the floor of the reservoir, keeps the mouth of the inlet sufficiently high to prevent the admission of any sludge; and the sludge is then admitted into the ejector B by opening a valve, and is transmitted by pneumatic force through a line of 4-inch cast-iron pipes, nearly a mile in length, to the destructor erected on the Chapel Wharf (Plate 2, Figs. 1 and 2).

The sludge is discharged into a cell, E, from whence it is drawn as required through a valve-pipe, and after mixture with road-sweepings in an incorporator, F, driven by a small steam-engine, is turned out as a good, dry portable manure which has all been readily bought up by agriculturists, since the commencement of the works, at 2s. 6d. per load delivered at the works. On an average, seventy cartloads of ash-bin contents are daily collected and destroyed, a small portion only being occasionally sold; and 25 tons of refuse, when burnt, generate sufficient steam for the carrying on of the works for one day, being about a fourth of the refuse collected in the borough, including the road-sweepings which are never burnt. In wet weather, the road-sweepings are stored and dried; and the fine ashes from the destructor are incorporated with the sludge in their place.

The refuse destructor has six cells or furnaces, each capable of burning 8 to 9 tons of garbage per day (Plate 2, Figs. 1, 2, and 5). The products of combustion pass through a 30-HP. multitubular steel boiler, in the main flue, to the furnace-shaft. There is also a by-pass in which a smaller boiler is placed, to enable the works to be continued during cleaning and repairs. No obnoxious fumes from the combustion have been perceived. The steam generated in the boiler is employed for driving the engines, G, of 31·5 indicated HP., which compress air into two large receivers, H H, whence it passes in a 5-inch main to the Town Quay, where it is automatically supplied to the ejectors when required for working them; and it also serves for driving the precipitated sludge through the main to the destructor, before referred to, being led from the receiver by a pipe to the head of the main at the Town Quay.

All obnoxious matters are collected throughout the borough in specially constructed, covered, iron tumbler-carts, which go up the inclined roadway approach to the destructor, and discharge

their contents direct into the cells. The road-sweepings are discharged into a hopper over the incorporator, and, after passing over a rocking-screen, are mixed with the sludge as required.

The residue from the continuous day-and-night combustion consists of about 20 per cent. of good hard clinkers and sharp fine ashes; the clinkers are used for the foundation of roadways and the manufacture of paving-slabs; the fine ashes are employed for mortar, as well as in the preparation of sludge for manure. Porous carbon is used for precipitating the sludge; it is mixed, with 1 lb. of sulphuric acid per cwt. and clean water, into a stiff paste, and led through a shoot, I, into a box, J, with perforated sides, placed in the sewer (Plate 2, Fig. 6). The sewage flowing past washes the carbon gradually out of the box, and is thoroughly mixed with the carbon by the time it discharges into the reservoirs at a manhole 150 feet off. A small stream of water falling down on the carbon prevents its consolidating. The box is filled three times in twenty-four hours; and this method of dosing the sewage has proved quite efficient and satisfactory.

A pressure of air of 40 lbs. on the square inch is required for working the sludge-ejector, and 10 lbs. for the effluent-ejector. Eight tons of sludge are dealt with per day; and arrangements were provided for burning the sludge. The sludge was discharged into a tank on the floor of the destructor, and drawn out through ports in the front opposite the feed-openings of the cells, where its moisture was absorbed by the ash-bin contents, backed up against the ports with this object; and the mixture was then raked into the fires (Plate 2, Fig. 5). Large quantities of sludge have been thus destroyed; but the process has been discontinued owing to the ready sale of the sludge when prepared for manure.

The Paper is accompanied with two sheets of tracings, from which Plate 2 has been compiled.

APPENDIX.

Working-expenses, and number of men employed upon the Southampton Sewage-Clarification Works:—

	Cost per Day.		
	£	s.	d.
<i>Labour—</i>			
One labourer attending at the precipitating-reservoirs, and mixing carbon with the sludge }	0	3	6
Two ditto ditto mixing manure in the incorporator, 3s. 6d. each }	0	7	0
One engine-driver	0	5	0

Materials—

Carbon, 10s. 5d.; sulphuric acid, 3d.; carriage, 2d. 0 10 10

£1 5 4

The annual cost per head of the population (13,000)
served by the sewage-clarification works is } 0 0 8½

By receipts from sale of manure for the year 402 0 0

Average per day 1 2 2½

On account of the returns from the sale of manure the
sewage-clarification makes but a trifling difference in
the sewage-rate.

HOUSE-REFUSE DISPOSAL WORKS.

The annual cost per head of the collection and disposal
of the house refuse, which relates to the whole borough
of 63,000 inhabitants, and would have to be performed
irrespective of the sewage-clarification, is } 0 0 4½

(*Paper No. 2285.*)

“Sizing Paper with Rosin.”

By JAMES WILLIAM WYATT, F.C.H., Assoc. M. INST. C.E.

PAPER, made simply from the interlacing or felting together of the constituent fibres into a sheet, is more or less porous, that is to say, the fibres cannot be so closely and compactly interwoven as to avoid leaving between them numerous small and minute interstices, or channels; these interstices, in virtue of capillary attraction, readily allow any liquid brought into contact with the paper to spread amongst and eventually to pass through the fibres. The fibres themselves, also, during the process of manufacture, are rendered quite pure, and the cells freed from all intercellular and glutinous matter, so that they readily absorb into the cellular canals water, or other liquids that may come into contact with them.

Paper in this condition is used for such purposes as blotting-paper, filter-paper, &c. It requires, however, further treatment to be used for writing, painting, drawing, and general purposes; the interstices between the fibres must be filled up and the surface of the paper rendered compact and non-absorbent by a substance which closes the pores of the paper, and binds the fibres together, and which must be insoluble in water, and impervious to writing- and printing-ink, colours, &c.

This treatment, known as sizing the paper, can be effected in two ways:—

(1) By dipping the paper when made into a warm solution of animal gelatine, or glue; it is then dried, and as the liquid evaporates, the gelatine is precipitated as a film, or skin, on both surfaces of the paper, and serves to protect it.

(2) By precipitating in the pulp amongst the fibres, before making into paper, rosin in a very finely divided state, which envelops and permeates the fibres. On passing the web of paper over the heated drying cylinders of the paper-machine, the rosin melts and runs into a compact mass binding all the fibres together and rendering the paper non-absorbent.

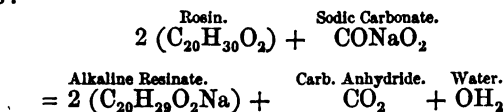
It is the latter of these two processes which is the subject of this communication.

In a few words, sizing paper with rosin is effected by first dissolving, or saponifying, the rosin with soda to form a resinous soap. This soap is next diluted to a working consistency, and added to the paper pulp with a solution of sulphate of alumina, or alum, which liberates or precipitates the rosin.

Rosin, or colophonium, the purified product or sap of different firs and pines, is a somewhat complicated substance, acid in its characteristics, but which, according to Dr. Wurster (a German chemist who has carefully studied the question of rosin sizing), can be conveniently represented by the formula $C_{20}H_{30}O_2$, its molecular weight being consequently 302. It commences to soften at a temperature of 120° Fahrenheit, and melts at 170° – 200° Fahrenheit. In combination with metallic oxides, rosin produces salts in which it plays the part of an acid; these combinations are called "Resinates." If this occurs with alkalis, the resinate dissolves easily in water, and forms a solution which froths strongly and possesses such decided characteristics of a soapy compound, that the alkaline resinates are generally called "soaps of rosin." The combinations with other metallic oxides are almost all either insoluble in water, or very slightly so; for that reason the addition of other metal salts to soaps of rosin causes the precipitation of insoluble resinates.¹

Of the different alkalis a soda compound, on account of its cheapness, is always employed to saponify the rosin; carbonate of soda, either in the form of crystals or soda-ash, is generally used for the same reason, and also because it is less troublesome to work than the caustic form. The acid characteristics of rosin are only weak; in a concentrated solution and with heat, the acid is sufficiently strong to drive the carbonic acid gas from the soda; in a diluted solution, however, and when cold, the alkaline resinate is decomposed to free rosin and soda by the addition of carbonic acid gas (CO_2).

The action of the Sodid Carbonate on the rosin may be expressed as follows:—



The neutral alkaline resinate, or soap of rosin, possesses the property of dissolving, or rather absorbing a considerable quantity of free rosin; or, in other words, it is able to prevent on cooling,

¹ Die Fabrikation des Papiers, by E. Hoyer, 1886, p. 235.

the collecting, or "balling," together of a surplus quantity of rosin which has become liquid during the boiling, and when diluted, to hold it in solution in such a finely divided state, that it remains suspended in the soap.

Free rosin in the soap is present either in solution, or in a state of emulsion (precipitation in a finely divided state) depending upon the temperature; in its ordinary condition, rosin melts at a temperature of about 170° Fahrenheit, but when suspended in the soap it melts at about 70° Fahrenheit; this is readily seen by taking a little soap in which there is a proportion of free rosin, on the finger, at first it has a thick yellowish appearance, but rapidly becomes brown and transparent owing to the heat of the body dissolving the free rosin.

The soap of rosin, or, as it is commonly called, "size," can be prepared in different ways, depending mainly upon the quantity of soda used in its preparation, and consequently on the proportion of rosin that is saponified, and that which remains in suspension in the soap in a free and finely divided state.

A simple test in making size, to show whether all the rosin is saponified or not, is to add a little chloride of sodium, or common salt, to the soap; this brings the surplus water, or liquor, away rapidly, because, in a solution of chloride of sodium, the soap of rosin is insoluble both in a hot and a cold state. Add now a little hydrochloric acid to the black liquid thus obtained, and if it contains soda, it will effervesce, due to the disengagement of carbonic anhydride (CO_2).

The alkaline resinate, or soap of rosin, is, as before mentioned, completely soluble in water; in an alkaline soda solution, however, it only becomes soluble when heated; therefore, when free uncombined soda is present in the soap, either by having an excess over the percentage necessary to saponify the rosin, or by not boiling sufficiently to combine all the soda present, it will rise on cooling to the surface in the form of a dark-coloured alkaline liquid, called "black liquor," containing as well the colouring matter in the rosin.

The molecular weight of rosin, represented by the chemical formula $\text{C}_{20}\text{H}_{30}\text{O}_2$, is 302, and that of carbonate of soda (CONaO_2) 106, or soda crystals ($\text{CONaO}_2, 10 \text{ OH}_2$) 286, and from the foregoing equation it follows that to produce the alkaline resinate one molecule of carbonate of soda is required for every two molecules of rosin; so that the proportion of carbonate of soda and soda crystals required to saponify the rosin is:—17½ per cent. of the former, and 47 per cent. of the latter; but as ordinary rosin contains quite

10 per cent. of water and other impurities, the quantity found by practice to be necessary is, about 41 per cent. of crystals, and 15 per cent. of carbonate. These quantities completely dissolve or saponify the rosin to form a soap which is altogether soluble in water without any opacity. An excess of this quantity is more or less superfluous, and on using a less percentage, a proportionate amount of rosin will remain suspended in the size, either in solution or in a state of emulsion.

To obtain 15–20 per cent. of the total rosin in a free state is the largest practicable percentage, as, if the proportion of soda is further reduced, it takes much longer to boil to release the CO_2 from the soda, and is difficult to dilute into a milk without some of the free rosin appearing as flocculent particles which affect the appearance of the finished paper.

A soap of rosin, in which the whole of the rosin is saponified, is known as “brown size,” and that in which there is a considerable percentage of free rosin, as “white size”; because in the former the soap is entirely soluble in water as a clear and transparent solution of a yellowish brown colour, whereas in the latter the proportion of free rosin (which in a finely divided state is very white) gives the solution a milk-white semi-opaque appearance.

It is of course possible to make a size more or less “white,” although the whole proportion of soda be used necessary to saponify the rosin, by not boiling it sufficiently to allow the soda time to combine with the whole of the rosin; in this case the superfluous soda will rise to the surface on cooling in the form of “black liquor.”

Dr. Wurster¹ found that a great natural affinity exists between rosin and the various fibres used in paper-making; this attraction seems to be especially strong at the moment when the rosin is precipitated from the resinate, for which reason the size has its best effect when this precipitation takes place in the fibres themselves. This molecular attraction of the rosin for the fibres, however, is not strong enough of itself to decompose the resinate, which must be done by adding to the pulp a sufficient quantity of an acid or acid salt which is more powerful than the acid action of the rosin in the resinate.

The use of free acids for this purpose is for many obvious reasons to be avoided, as a slight surplus must always be used to give to the pulp or finished paper an acid reaction. An alum salt is the one always employed to precipitate the size; all soluble alum salts

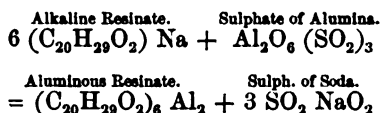
¹ Dingler's 'Polytechnisches Journal,' No. 226, p. 75, &c.

can be used for this purpose, but only those in combination with sulphuric acid, as sulphate of alumina and crystal alum, are ever employed, because they are the most easily obtainable. The percentage of alumina contained in the alum salt, and the price and degree of purity at which it can be produced, will go to determine which alum compound to use.

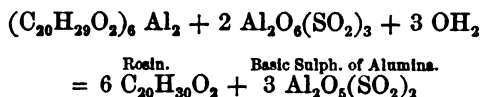
Potash alum contains	10·8 per cent. alumina.
Soda " "	11·2 " "
Ammonia,, "	11·4 " "
Commercial sulphate of alumina contains about	15·4 " "

As sulphate of alumina can now be produced cheaply and practically pure (*i.e.*, free from iron and free acid), it has almost entirely superseded the use of crystal alum for making size; where the latter is used, the quantity required over that of sulphate of alumina will be in proportion to the percentage of alumina contained.

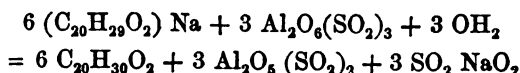
The action of the sulphate of alumina on the alkaline resinate is represented by the following chemical equations:—



On adding an excess of sulphate of alumina to the aluminous resinate thus formed free rosin is deposited, and the sulphate of alumina is transposed into a basic sulphate of alumina as follows:—



or combining the two in one operation:—



From the above it will be seen that to produce the aluminous resinate one molecule of sulphate of alumina is required for every six molecules of rosin; and to transform all the alkaline resinate to free rosin three molecules of sulphate of alumina are necessary to every six of rosin. The molecular weight of rosin is 302, and

that of sulphate of alumina 343, so that the requisite proportions of rosin to sulphate of alumina in precipitating the size are :—

To produce the aluminous resinate	. . .	5·28 : 1
„ „ „ rosin	. . .	1·76 : 1

But as commercial sulphate of alumina contains always about 50 per cent. of water, and ordinary rosin about 10 per cent. of water and other impurities, the proportions in actual practice become :—

2·93 : 1 for the former
0·98 : 1 for the latter.

Of course in the case of white size, the quantity of sulphate of alumina required is reduced in the same proportion as the percentage of free rosin contained in the soap, so that with a size containing 20 per cent. of free rosin, the proportions would become :—

3·66 to 1 for the resinate
1·22 to 1 for rosin.

The above calculations are to some extent theoretical, as the exact composition of rosin is not perfectly understood, and the formula of $C_{20}H_{30}O_2$ is taken by Dr. Wurster as being nearest the truth; the proportions are, however, well borne out by practice, as the lowest proportion of sulphate of alumina to rosin that has been found practicable in mills where the water is exceptionally favourable is 1 to 1.

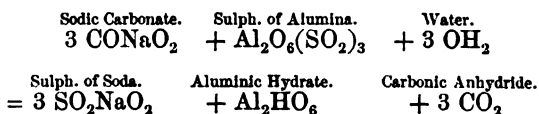
It is a matter of question among chemists how the sizing of the fibres is really effected. Dr. Wurster maintains that it is only the free rosin that produces the real sizing effect, and it has been proved possible to size paper well by merely mixing finely pulverized rosin with the stuff in the engine; others again hold the opinion that it is effected partly by the free rosin and partly by the aluminous resinate. Considering, however, that it is nearly always advisable to add such an excess of alum or sulphate of alumina to the pulp that the paper shows a slightly acid reaction to the litmus paper, and that before such an excess can make itself shown, all the aluminous resinate must have been converted into free rosin, it would appear that in almost every case the sizing is effected by the free rosin entirely.

As regards the respective merits of “brown” and of “white” size, somewhat will depend upon the arrangements and requirements of the manufactory, on the degree of hardness of the

water used, &c. It is a fallacy to believe that the size when precipitated with alum is whiter with white than with brown size; it is as white from the one as from the other, the diluted soap or milk of rosin only being whiter with the former than with the latter, owing to the presence of the large percentage of free rosin.

White size sizes somewhat harder and better than brown size, it is therefore more generally used in the manufacture of writing and other hard-sized papers; the reason of this is not very easy to determine, the precipitate of brown size by alum is coarser and more flocculent than that of white size, and it is possible that the finer precipitate from white size more thoroughly penetrates the cells of the fibres to be sized, and therefore produces a better sizing effect in the paper.

White size is also less expensive to use, as it needs less soda in the manufacture, and less alum to precipitate it owing to the proportion of uncombined rosin. It can also be used sooner after being made than brown size, since all the soda being in combination there is no black liquor to come away; brown size requires to stand some time before using if good size is to be made from it, as if all the free soda is not allowed to come away, it will take more alum to neutralize it in the pulp, and besides liberates carbonic acid gas giving froth on the paper-machine, as follows:—



White size is much less simple to make and use than brown size owing to the free rosin in suspension in the soap; if this is not of a fixed and strong degree of concentration, the free rosin, when the size is diluted to milk, tends to separate itself in a flaky form, and will show in the finished paper as light and transparent spots. Brown size, being a pure alkaline resinate, is entirely soluble in water, and the degree of concentration of the soap is not of moment; it is, therefore, a simpler preparation, and more easily made and understood by ordinary workpeople.

One slight drawback to the use of white size is, that small particles of the uncombined rosin fix themselves on the sides and edges of all the tubs and pails in which it is used. Great care must be taken that these small particles do not get into the stuff, or they will show up in the paper, and this is only to be avoided by keeping everything scrupulously clean and well filtering the size into the beating-engine through a fine wire cloth.

The following are usual proportions for the manufacture of the two forms of size :—

<i>White Size.</i>	<i>Brown Size.</i>
100 lbs. rosin.	100 lbs. rosin.
12-13 lbs. pure carbonate of soda (Solvay soda, 58 per cent. of sodic oxide, Na_2O).	15-16 lbs. Solvay soda, 58 per cent.
75 lbs. water.	About 110 lbs. water.
Gives 140-145 lbs. soap of rosin.	Gives about 230 lbs. soap of rosin,
4 to 4½ hours' boiling.	= about 160 lbs. " "
	after the black liquor is decanted.
	3¼ to 3½ hours' boiling.

White size must be boiled with indirect steam through a steam-coil, or better, in a steam-jacketed pot, in order that the degree of concentration of the soap shall not vary; but with brown size it does not matter, and direct steam can be used. In using a steam-coil or steam-jacketed pot, care should be taken that the coil or steam-jacket is below the level of the soap in the pot, as, if not, the froth that forms on the surface of the mixture when boiling gets superheated, rises rapidly, and flows over the edge of the pot, unless a little oil or tallow be used to kill it, which should be unnecessary.

The water is first put into the pot, the soda dissolved in it, and the solution brought just to the boiling point; the powdered rosin is then gradually added, stirring well the whole time. The boiling must be conducted with care to prevent the froth rising and overflowing, the mixture being kept slowly boiling until the size is ready, when it is run down into vats to store and strained through a coarse sieve. In order to see that the soap is ready and the boiling sufficient, dissolve a little in lukewarm water; the solution should be quite clear or milk-white, without any rosin appearing either in flakes or brown strings.

With brown size, unless there is ample space to allow the soap to store and give time for all the black liquor to rise, it is advisable to mix a little common salt with the soap when the boiling is finished, which brings the liquor away rapidly, as previously explained. About 1 lb. to 2 lbs. of salt per 100 lbs. of rosin will be sufficient, depending on the length of time the soap can be allowed to store.

White size can be made in three ways :—

- (1) By boiling with too little soda, as in the figures above given.
- (2) By boiling with sufficient soda, but not long enough to saponify all the rosin, and then taking off the superfluous liquor.
- (3) By making first a completely soluble soap or brown size,

and then adding and dissolving in the mixture the required percentage of fresh rosin.

The first is the method usually adopted, as the second is waste of soda, and the third is troublesome and gives extra labour in a mill, which is to be avoided.

Before using the soap of rosin it should be diluted to a working consistency, so that 1 gallon of the solution contains from $\frac{1}{4}$ lb. to $\frac{1}{2}$ lb. of rosin; it is not well to work the size too concentrated in the beating-engine, it does not amalgamate rapidly enough; indeed, with white size the careful preparation of a diluted solution is essential to ensure the free rosin not separating from the soap in flocculent masses. Brown size can be diluted cold, as it is all soluble, but it is better diluted in lukewarm water, as it dissolves more readily; but with white size it is necessary to dissolve it first with warm water at a temperature of about 120° Fahrenheit, and then to thin the solution down to the desired working consistency with cold or lukewarm water; the reason of this is, as explained before, that the free rosin, present in the soap when below a temperature of about 70° to 75° Fahrenheit, is in a state of emulsion, whereas it melts at a higher temperature, so that if the soap is dissolved cold, the alkaline resinate dissolves and leaves the free rosin in large flocculent masses; whereas if diluted warm, the free rosin is dissolved with the soap, and on cooling appears again in finely divided particles, owing to the thinness of the solution.

The action of the size is materially increased by an admixture of starch, it helps to bind the rosin more to the fibres, and increases its yield in the paper. About 1 lb. of starch to every 5 to 8 lbs. of rosin is a usual proportion; the starch must first be mixed with lukewarm water in the mixer or pot, and the temperature raised until it thickens, generally from 160° to 180° Fahrenheit, depending on the kind of starch used; water is now added to reduce the temperature to that necessary for dissolving the soap, which is then added in the usual way.

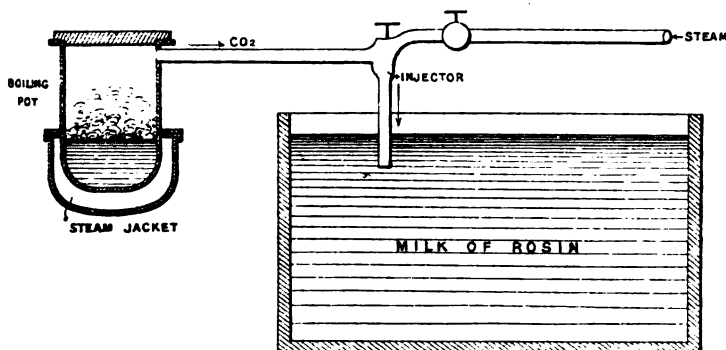
In some mills working with brown size, the carbonic acid gas, given off when boiling the rosin with soda, is passed by means of a steam injector through the "milk of rosin" (as the solution of size is called), already diluted, and before being used in the engine, in such a manner that the CO₂ produced by one boiling is passed through the milk of rosin also produced by one boiling, as shown by Fig. 1. The object of this is to increase the quantity of free rosin in the size, in other words, to produce a white size, as the CO₂ when passed through a cold and diluted

solution of size combines again with the soda, and liberates the rosin in a finely divided state. It thus improves the size by increasing its sizing effect; but no less alum is required in the engine to set the size, as what is not required for the size, is required to neutralize the alkaline solution of sodic carbonate formed.

The size should be well filtered through a fine wire cloth when it is added to the pulp, and it is also as well to filter it after diluting the soap into milk when running it into the storage-tank.

The necessary quantity of rosin to size paper well depends greatly upon the materials to be sized, upon the way they are prepared, and upon the requirements of the paper itself and the substance of which it is made. For ordinary printing-papers $2\frac{1}{2}$ to

FIG. 1.



3 per cent. of rosin will be found sufficient, and for thinner papers and those used for writing purposes $3\frac{1}{2}$ to 4 per cent., or even more, will be required. Of these quantities, the yield in the finished paper will be about 75 to 80 per cent.

In practice a very much larger quantity of alum, or sulphate of alumina, than that given in the foregoing proportions for precipitating the size is required to acidify the paper-pulp, owing mainly to the degree of hardness of, and other impurities in, the manufacturing water used; and in a lesser degree to neutralize other alkaline substances used in the manufacture, such as soap, free soda contained in the size, antichlor, &c. The quality of the water used in a paper-mill therefore may and often does become the great source of expenditure of alum, and the quantity required varies usually from 1 lb. of alum per 1 lb. of rosin to as much as 3 lbs. of alum per 1 lb. of rosin. Not only the water that is filled into the beating-engine has to be neutralized, but also what is used to

empty the pulp down the stuff-chests and the fresh-water used on the machine. The quantity required for this purpose can readily be determined in any mill, and must be a fixed quantity always added to the pulp, whether the paper be sized hard or soft, and then the requisite quantity necessary to precipitate the size.

In some paper-mills, particularly those making writing-papers and papers requiring a hard and rattling handle, a much larger quantity of alum is added to the pulp than is required for size or to neutralize the alkaline substances in the water, &c., with the idea that it sizes the paper harder and gives a better handle. An excess of alum, however, could not render the sizing more efficient, and it is probable that the increased hardness of the paper is due more to the acid action of the alum on the fibres themselves, rendering the cellulose more dense and gelatinous in the same manner that parchment paper is made by treating the fibres with sulphuric acid.

It is a matter of considerable importance in what manner and succession the size and alum are added to the pulp. Some contend that the best effect is produced by first adding the alum and then after a short time the size, and others take the opposite view.

It has been mentioned before that rosin, especially when in "*statu nascendi*," so to speak, has a remarkable affinity for the fibres, and the Author is of opinion that the sizing is more sure if the size is added to the pulp first, so as to get well beaten in with the pulp; then when the alum is added the rosin is precipitated in the fibres themselves at a time when it has the greatest affinity for them, and not on or about them. In either case a sufficient time (say three-quarters of an hour) should elapse between the two, so as to allow the one or the other thoroughly to get incorporated with the fibres first. If the rosin is added to the pulp as soon as the engine is filled, and before the stuff is reduced at all, it often produces, especially with rag stuff and strong fibres, a heavy frothing which is very inconvenient, and for that reason many manufacturers add the alum first to the pulp, so that the rosin is precipitated as soon as the size is put in. The best way is, if the style of beating-engine will permit it, to add the size about an hour before the engine is finished beating, and the alum about one-quarter of an hour before emptying. If the water is very hard it becomes more important that the alum should not be added first; so very much more alum is used than is required for the size, and also as previously explained, for the emptying water and that on the machine as well, that the pulp in the engine is very acid, and the size when added is precipitated immediately and all in one

place, so that it does not get well mixed with the fibres, and the sizing is irregular and not so good.

Frothing, on the paper-machine principally, is the most troublesome circumstance in connection with the rosin-sizing, and although it can be minimized and reduced so as to be no longer troublesome, it can never be entirely avoided. It is a somewhat complicated question, and would seem to be due to many causes both in connection with the manufacture of the size itself, as well as the manipulation of the pulp and the arrangements of the paper-machine, but more especially the two latter.

The most fertile source of frothing is a badly arranged paper-machine from the mixing-box to the wire. All undue agitation or lifting of the back-water and stuff should be studiously avoided, and the machine so arranged that the stuff and back-water flow as quietly and steadily as possible, and without sudden drops and waterfalls from the mixing-box to the wire, the level or fall between these two to be as small as practicable.

The use of the back-water running from the wire to dilute the pulp on the machine is a great source of froth, as it contains the finer particles of rosin, starch, &c., that pass through the wire from the pulp; the pumps for stuff and back-water should be so speeded as to raise little more than the quantity actually required on the machine; indeed, for the back-water, a bucket-lifting wheel, if it can be used, works more quietly and with less frothing than a pump. The Author has seen in a paper-mill two machines of similar construction and running on similar papers, the back-water in one case lifted quietly to the mixing-box by means of a bucket wheel, and in the other by the ordinary force pump; the former machine was very free from froth, while the sand-traps and slices of the other were covered with it.

The sand-traps should be well constructed, so that the stuff may flow to the strainers quietly and uniformly, and not too quickly.

Bad strainers are sometimes a fertile source of frothing due to faulty construction or bad design, and requiring too violent agitation.

Warming the stuff by steam in the mixing-box much increases the tendency to froth, as is the case with any solution of a soapy nature when agitated warm. It is questionable whether this is not increased by the agitation due to the entry of the steam in the pulp, and whether it would not be better heated by a steam-coil or steam-jacketed box.

There is not usually so much frothing with slower-running machines and when making thicker papers, as there is not so much

agitation and quick running of the stuff; besides, the thickness of the paper enables the fibres to hold the size better, they do not need so much water on the wire to shake them together, and there is much less back-water coming round.

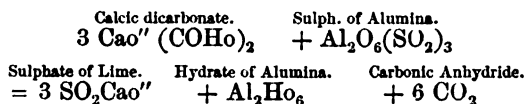
Frothing depends also very much on the quality of the materials used and how they are worked in the beating-engine. The fibres of some materials, such as flax, hemp, esparto, &c., are more dense and solid, consisting of cylindrical hollow cells or tubes with thick walls; when these are opened out and bruised under the action of the roll, they work more or less what is called "wet," that is to say, they have an affinity for absorbing and retaining water; these allow the size to penetrate readily and retain it better than such fibres as cotton, wood, &c., the cells of which are thin and flat, like ribands. Consequently a paper made from the former materials holds the size better in the cells of the fibres, and does not allow so much of it to pass away with the back-water, therefore making less froth.

What is known as "free" or "fast" stuff, where the fibres are more cut up in the beating-engine than bruised and drawn out, is never sized so well as when the material is well "wetted" by being more gradually beaten, because the fibres are not sufficiently opened up, and the size, instead of penetrating the cells of the material, is more deposited on the surface of the fibres with not nearly such a good or uniform effect. To size paper well, the fibres from which it is made must be pure, i.e., free from all foreign matter, such as gummy and resinous materials, chlorine, &c.; in fact, anything that either weakens the size or prevents it being absorbed into the heart of the fibre.

Dr. Wurster says that white size froths more than brown size on account of the finer state of division and precipitation of the rosin in the former than in the latter; but the Author after trying both could see very little difference in this respect between the two. When starch, however, is mixed with the milk of rosin, as is often done to strengthen and affirm the size, it makes the froth much more troublesome, not necessarily causing more, but making it firm and stiff, so that it will not disperse; the small bubbles of froth that escape under the slice, instead of breaking in their passage down the wire, get broken at the dandy-roll and cause pin-holes in the paper, especially with the thinner substances. Indeed, on quick-running machines making thin papers, the Author has been obliged for this reason to leave the starch out of the size altogether, the froth being then no longer troublesome; and when the froth was tested in the usual way for starch with iodine, it was found to contain a large quantity.

Size made with free soda, and which is not stored long enough to allow it all to come away, froths more on account of the CO_2 formed as before explained.

Hard water is also a cause of frothing, as when agitated and rendered acid, as it usually is in the pulp, it liberates carbonic acid gas, as follows:—



Heavy frothing, particularly when the froth is stiff and heavy, may cause a considerable amount of trouble by obstructing the flow of stuff along the shoots and sand-tables, giving rise to a varying and un-uniform flow of the stuff, and consequently irregular weight of paper on the machine.

It has been suggested, when frothing is troublesome, to fix a tube, perforated with very small holes so as to give a fine spray of water, over the mixing-box, and break or lay the froth as it forms, and as well to have a similar spray before the first slice, and before one or two boards along the sand-table, fixed on end just above the stuff to arrest the froth and disperse it; but the Author has never tried it, although the idea is good. The use of a little oil or petroleum in the beater or mixing-box is the common remedy for frothing; but although this has an undoubted effect, its adoption is to be avoided if possible, as unless used with moderation and caution, it produces a dark-coloured scum in the paper.

The finely divided and precipitated rosin that sizes the paper is of a fine white colour that does not lower the colour of the pulp; as it melts, however, it becomes yellow in colour; therefore, in making engine-sized papers, care must be taken not to have the drying cylinders over-heated, or to have a sufficient number of them so that this is not necessary. The Author has frequently seen the colour of an engine-sized paper lowered when made on a machine with insufficient drying cylinders, which had to be over-heated to dry the paper thoroughly, and the same paper made on a machine with ample drying power with the colour unimpaired.

Paper sized with rosin-size is sized for neutral or slightly acid liquids, and not for alkaline. The inks used must therefore be neutral or only slightly acid; an alkaline ink will penetrate the paper unless the latter has a strongly acid reaction, and then it will not resist the ink if it is very alkaline. The commoner kinds of red ink try the sizing severely, as they often contain alcohol, in which rosin is soluble.

The question of rosin-sizing is a complicated one, and the action of the size in the fibres of the paper still but imperfectly understood. The effect of the size will depend much upon the quality of the water used in the manufacture, the condition of the materials required to be sized, and other important factors, which vary considerably in mills working in different situations and under different conditions.

In many cases the manufacturer finds out by practice what is necessary for his purpose, without always satisfying himself as to the why and the wherefore; and it would go a great way towards getting at a clearer conception of this important question, to study the results obtained from a number of different paper-mills together with the conditions under which they were working, and to do this in connection with a thorough chemical research into the question, without which all investigations of this nature are conducted more or less in the dark.

It has also yet to be discovered how to size paper in the pulp with rosin or other substances, and to produce the same result in the paper as regards handle and finish as when it is animal-sized with gelatine in the web or sheet. This has not yet been done.

The Paper is illustrated by a diagram, from which the Fig. in the text has been prepared.

(*Paper No. 2271.*)

“The Sulina Mouth of the Danube.”

By CHARLES HENRY LEOPOLD KÜHL, M. Inst. C.E.

DESCRIPTIONS of the delta of the Danube, of the works executed at the Sulina mouth, and of the changes effected by these works up to 1873, when a minimum depth of water of 20 feet had been obtained, have been given by Sir Charles A. Hartley, K.C.M.G., M. Inst. C.E., in his two Papers¹ read before the Institution in 1862 and 1873. The Author proposes in this Paper to describe the changes which have taken place at the Sulina mouth since 1872.

By dredging away a small shoal in 1873, consisting of wreckage, ships' ballast, and stones, on the site of the old bar between the piers, 2,000 feet to the west of the north pier-head, the depth of the entrance-channel was increased to 20½ feet; and, except during two short intervals, this depth has been maintained ever since. The insufficiency of the extension of the south pier, for 457 feet in 1869–70, was first manifested in 1873, when the south sand-bank curled round the south pier-head as formerly, the 3-fathom line projecting 200 feet into the jetty-channel, under the lee of the 204 feet of overlap of the north pier; and this line remained in nearly the same position during 1874 (Plate 3, Fig. 1). The bank, however, was entirely swept away by the strong flood-current in April, May, and June 1875, but reappeared in an aggravated form in March 1876, extending half-way across the entrance, and reducing the effective depth to 19½ feet from the 22nd of March to the 14th of April. The depth then increased to 20 feet, and reached 20½ again on the 1st of May; and the very strong river-flood, lasting from April to August, swept away every vestige of the bank before the end of the year. To prevent the recurrence of a similar shoaling, the south pier was extended 204 feet, bringing its extremity exactly opposite the north pier-head, so that now the full current is maintained to the ends of the piers. Any sediment deposited by the river beyond the ends of the piers is directly exposed to the combined action of the heavy

¹ Minutes of Proceedings Inst. C.E. vol. xxi. p. 227; and vol. xxxvi. p. 201.

seas, produced by N. to N.E. gales, and the littoral current from the north, and is swept away southwards. The possible amount of this deposit is plainly shown by the survey of March 1879 (Plate 3, Fig. 2). The river having broken up the ice in the middle of February, rose to its greatest recorded height, 14 feet 5 inches above the zero-level of the Black Sea at Toultscha, 50 nautical miles up-stream, flooding the whole delta, and extending the south bank further than has ever happened before or since. Fortunately the bank formed to the south of the south pier, in an easterly direction, instead of extending northwards as on former occasions.

The river-floods, during the four years 1876-79, effected a great scouring out of the channel between the piers in forcing a passage for the increased volume of water, an increase in depth of 10 feet and more being produced in many places where the river-bottom was favourable for erosion. This great deepening by natural scour is readily seen by comparing the surveys of July 1873 and of March 1879 (Plate 3, Figs. 1 and 2). In the latter survey, there is an extensive hole in the jetty-channel near the head of the south pier, with a maximum depth of 30 feet (which increased to 32 feet in July); whilst the deepening near the north pier-head is considerably less in extent, with a maximum depth of 27 feet. In July 1879, an isolated bank formed in mid-channel, 300 feet beyond the pier-heads, in a depth of $20\frac{1}{2}$ feet. This bank developed so rapidly, owing to the river being at the height of flood and fully charged with detritus, that it reduced the available depth at the entrance to 20 feet on July 24th, and to $19\frac{1}{4}$ feet on July 25th; but the depth increased again to 20 feet on August 1st, and to $20\frac{1}{2}$ feet on August 26th, 1879. As the undue deepening of the river near the end of the south pier (aided by the deepening near the north pier) was evidently the main cause of the irregularity of the channel beyond the pier-heads, and of the formation of the bank just described, by attracting a great proportion of the river-water and directing it into a blind channel to the south, a sill of rough ballast, from the ballast-heaps formerly discharged by sailing-vessels, was formed towards the close of 1879 between the pier-heads over a width of 100 feet, leaving a depth over it of 25 feet below zero (Plate 3, Fig. 3). This sill produced a regular channel by distributing the discharge between the pier-heads; and the normal depth at the entrance of $20\frac{1}{2}$ feet has been constantly maintained at all stages of the river. In May 1881, when the river-flood was at its height, a bank analogous to the one of July 1879, but with modifications, formed

outside the pier-heads (Plate 3, Fig. 4). As, however, a good channel was maintained, about 400 feet wide, between the north pier-head and its limit northwards, and as the bank disappeared by the middle of June without artificial aid, it did not interfere with the navigable depth of the channel.

A regular cycle of changes occurs in the jetty-channel, as well as outside. During the discharge of a heavy land-flood, the jetty-channel is scoured out, sometimes to a depth of 25 feet, throughout the fair way, and its cross-section enlarged to 14,000 square feet (Plate 3, Fig. 5); whereas during a long period of low water in the river, deposit reduces the depth to about $20\frac{1}{2}$ feet (Plate 3, Fig. 6), and the cross-section decreases to 10,400 square feet. The channel beyond the pier-heads is affected by the movements of the south bank, which advances east and north with the deposit of a river flood. The bank recedes during the low stage of the river under the erosive action of the sea, at the period of the autumn and winter gales, when N. to N.E. winds prevail. The south bank consists of very fine sand almost free from silt, as the light mud in suspension, or washed out by the waves, is carried out to sea and deposited in still water far beyond the reach of the river current. Generally there is a depth of $20\frac{1}{2}$ feet in the fairway outside the pier-heads, in the line of the old Sulina and north pier lighthouses, which increases to $21\frac{1}{4}$ feet during the winter months, and decreases to 19 feet during river floods, when, however, the requisite depth of $20\frac{1}{2}$ feet is always found very little to the north of the leading line. Thus the greatest depth of the jetty-channel coincides with the least depth outside, and *vice versa*.

Comparing the general condition of the Sulina entrance at present, and in 1871, it appears that the south bank has steadily developed, and the 5-, $4\frac{1}{2}$ -, 4- and $3\frac{1}{2}$ -fathom lines have advanced 1,400 feet to the north-east, or 93 feet seawards per annum (Plate 4, Fig. 1). This advance gradually diminishes towards the south, till it ceases 2 miles south of the pier, and further south the coast is being eroded (Plate 4, Figs. 2 and 3). Due north from the pier-head the 5-fathom line alone has advanced to the extent of a minimum of 100 feet during the fifteen years 1871-86, whilst the shallower lines of soundings have been thrown back towards the north beach. Owing to this constant deepening of the bay to the north, and its enlargement by the abrasion of the north beach, the undertow seawards during north to east gales is constantly increasing, which augmenting the scour near the north pier-head, on joining the combined littoral and river currents, produces a gulley in front of the pier-heads, with a depth at the

north pier-head varying between 28 and 30 feet, which communicates by a due north deep channel with the deep water beyond. The first survey of the Sulina mouth,¹ in July 1857, shows a depth of 18 feet, 500 feet to the north of the site of the present north pier-head, where there is now 27 to 28 feet of water increasing in depth northwards. So long as this deepening action continues there will always be a channel to the north, 25 to 27 feet deep, which though not itself available for navigation, owing to its sudden turn northwards, will secure a channel of adequate depth in a suitable direction for navigation. This would be more assured if the 5-fathom line had continued its approach to the north pier-head after 1876, as previously (Plate 4, Fig. 1), instead of gradually receding northwards since that year—a change which can only be accounted for by the large quantity of deposit brought down by the enormous floods of 1876–79, 1881, and 1883, and the great advance of the Kilia delta (Plate 4, Fig. 2). The north pier, projecting 5,600 feet from the shore, measured in a direct line from the root to the pier-head, at an angle of 110° to the north beach, acts as a long groyne to the littoral current impinging on its northern face, which causes the scour at its head. This scour would continue its action southwards, past the south pier-head, if not arrested by the river-current, which rapidly fills up any deepening in that direction with the sand and deposit discharged during floods, and dropped outside immediately on emerging from the trained channel in a south-easterly direction. The direction of the current, resulting from the confluence of the river and the littoral-current, is plainly indicated by the 2- and $2\frac{1}{2}$ -fathom lines going in a south-easterly direction from the south pier-head, at an angle of 58° to the south pier extension, which is the measure of the present deflection.

The erosion by the sea necessitated the extension of the north pier 694 feet landwards by 1871; it had to be prolonged 150 feet in 1873, and 200 feet more in 1876, and the total prolongation reached 1,100 feet in 1883; and as the rate of erosion is increasing, further extensions will become necessary from time to time. The land carried away is a swampy waste covered with reeds, and is therefore not worth protecting; and the enlargement of the bay is advantageous in increasing the volume of the undertow, and consequently promoting the scour near the pier-heads. The north beach, composed of an insignificant belt of very fine drift sand overlying the marsh, is easily penetrated by every gale, leaving

¹ Minutes of Proceedings Inst. C.E. vol. xxi. plate 7.

bare a strip of alluvial and peaty soil which is rapidly removed by the waves. The beach in the angle at the root of the north pier was protected, in 1876, by depositing ships' ballast and shingle from hopper-barges in front, which was quickly driven in by the waves to form a beach; but beyond the influence of this artificial protection to the north, the erosion continues as before. The abrasion of the north beach amounted to 555 feet from 1871 to 1886, or 37 feet per annum. The south beach has advanced 400 feet with the prolongation of the south pier, but appears to have attained a state of equilibrium some years ago.

The south pier extension of 1869-70 was consolidated, like the previous works, in 1879, and the extension of 1876-77, in 1885-86, thus converting these additions into permanent structures, the head being protected by 15-ton concrete blocks deposited at random. The seaward side of the north pier has been protected with one hundred and sixty-four 7 ton concrete blocks, and six hundred and twenty-seven 15-ton blocks, deposited at random along the whole length, the spaces between them being filled up with concrete in bags. These blocks act as a wave-breaker, but their principal object is to protect the mound of rubble, outside the sheet-piling forming the foundation of the pier, from being dislodged and thrown over the pier during gales, and from travelling towards the root under the influence of north-easterly seas.

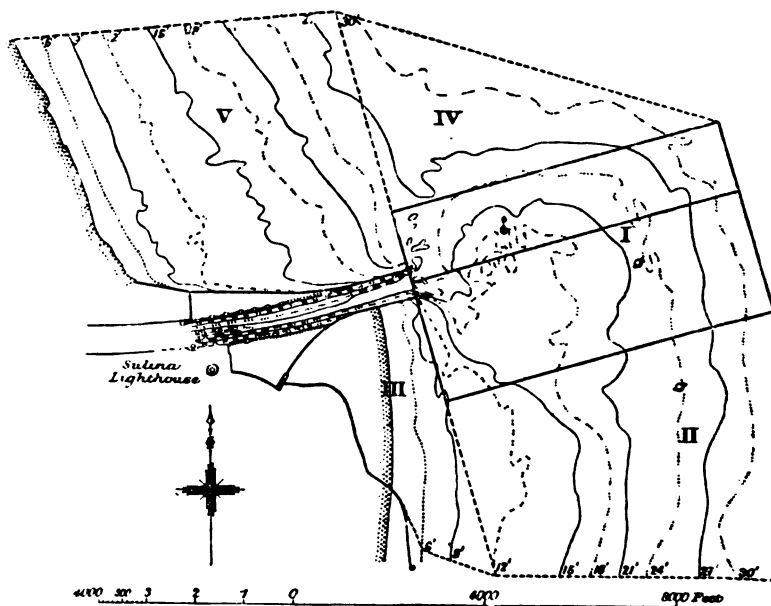
The Paper is accompanied by a series of tracings and a plan, from which Plates 3 and 4 have been compiled.

APPENDIXES.

- I. TRANSLATION of a portion of a REPORT addressed by Sir CHARLES HARTLEY, in June 1887, to the EUROPEAN COMMISSION of the DANUBE, relative to changes that have taken place in the bed of the sea adjacent to the SULINA MOUTH during a period of twenty-nine years.

The annexed Map (Fig. 1) and Tables 1 and 2 have been prepared, under my direction, for the purpose of explaining the

FIG. 1.



THE SULINA MOUTH OF THE DANUBE.

The contours refer to the soundings in feet in June 1887.
Scale 1 inch = 4,000 feet.

nature and extent of the principal changes which have been observed in the depths of the sea at the Sulina Mouth from July 1857, the date of the first survey of the European Commission of the Danube, to November 1886. The area immediately outside the pier-heads is divided into five zones, which together embrace

an area of 2,691 acres, or 4·2 square miles. Zone I, of 642 acres, has been especially studied during a period of twenty-nine years, in order to show the comparative state of the entrance directly in front of the pier-heads at various intervals. Although the changes that have taken place in Zones II, III, IV and V, comprising an aggregate of 2,049 acres, have been deduced from data of a less precise character, the result is sufficiently exact to give a general idea of the amount of deposit and scour immediately adjacent to Zone I during the same period. Zone I is divided into two sections, north and south, by the prolongation seawards of the axis of the channel between the piers to the depth of 33 feet, or 7,000 feet from the pier-heads. The width of the northern section is 1,500 feet, and of the southern 2,500 feet, which gives an area of 239 acres and 403 acres respectively.

Table I (p. 338) shows that from 1857 to 1871 the thickness of deposit over the 642 acres of Zone I was 2·69 feet, and from 1871 to 1886 2·17 feet, or 4·86 feet during a period of twenty-nine years; and that whilst the deposit from 1857 to 1871 was 2,784,379 cubic yards, it was only 2,610,290 between 1871 and 1886, without any deduction for the scour of 355,733 cubic yards that took place during the latter periods. It also shows that, in both sections, the total deposit was greater during the first period of fourteen years than during the second of fifteen years, although the volume of deposit, carried to sea in suspension by the Sulina branch, was 45,965,200 cubic yards from 1871 to 1886, and only 42,487,100 cubic yards from 1857 to 1871.

Table II (p. 339) contains the result of all the calculations which have been made to find approximately the importance of the changes in the depth of the sea over the area of the five zones shown on the plan (Fig. 1). Zones I, II, III, and IV, having a total area of 1,910 acres, or about 3 square miles, have experienced, during twenty-nine years, a deposit of 15,526,528 cubic yards, and a scour of 2,977,611 cubic yards, which gives a resulting deposit of 12,548,917 cubic yards, or, on an average, 432,720 cubic yards a year. The volume of sediment carried in suspension by the Sulina branch during twenty-nine years being 88,452,300 cubic yards, the proportion of deposit, irrespective of scour, spread over an area of 3 square miles, has been 17·55 per cent. of the volume of detritus in suspension discharged by the river. In other words, of the total volume of sediment discharged in suspension between 1857 and 1886, a proportion of $17\frac{1}{2}$ per cent. has been distributed over an area of 3 miles in the vicinity of the piers, and $82\frac{1}{2}$ per cent. has been dropped further seaward. So far as Zone V is

concerned, a comparison of all the soundings show that there has never been any deposit to the north of the north pier, and that the total scour of 4.75 feet, within an area of 781 acres, has produced an erosion of 5,977,104 cubic yards. Taking this large amount of scour into consideration, and adding to it the erosion that has taken place over portions of the areas of Zones I, II, III and IV, it appears that the resulting deposit, over the total surface of 2,691 acres, has only been 7.43 per cent. of the total amount of sediment carried in suspension by the river. It is remarkable that the depth of scour in Zone V, 4.75 feet, from 1857 to 1886, is nearly identical with the average deposit, 4.88 feet, which is found in Zones I, II and III. It is not to be supposed, however, that the material scoured away from Zone V contributed even partially to the growth of the banks facing, and to the south of the entrance; for, on the contrary, it is evident that all the material scoured from the north of the north pier, Zone V, has been transported to great depths at sea by the action of the littoral current and northerly winds. It is to be observed that the calculations of the volume of sediment carried in suspension by the Danube do not include the sand rolled along the bottom of the river, the amount of which cannot be even approximately estimated, but which at times of high floods probably exceeds the volume of detritus carried to sea in suspension.

Although the growth of the banks in front, and to the south of the piers, is due to river detritus alone, it can never be foreseen what will be the real effect on the sea-bottom when the river waters are heavily charged with sediment; for the rate of advance of the submerged banks at that time depends entirely on the velocity of the river and littoral current, and on the force and direction of the wind. If the wind is from the west, the deposit is small; but if, on the other hand, it blows from the east or south, or if there is no wind at all, the growth of the banks in front of the entrance becomes very marked. Table I shows a remarkable result, confirming the theory that the development of the banks in front of the piers is far from being even approximately proportional to the amount of sediment discharged by the river. Thus, on referring to the same Table, Zone I, it will be noticed that, although the sedimentary matter in suspension amounted to 13,670,150 cubic yards from 1871 to 1876, and to 32,295,050 cubic yards from 1876 to 1886, the proportion of new bank deposit to suspended detritus was 10.65 per cent. during the first period of five years, and only 3.57 per cent. during the succeeding period of ten years.

Notwithstanding that the advance of the $3\frac{1}{2}$ -, 4-, and 5-fathom lines of the Sulina delta in the direction of the axis of the piers (E. $\frac{1}{4}$ N.E.) has been 1,350 feet, 1,700 feet, and 1,350 feet respectively, during the fifteen years ending 1886, the advance of the $3\frac{1}{2}$ - and 4-fathom lines in the north-easterly direction of the fairway has only been 500 feet and 900 feet respectively, whilst the 20-foot contour has been stationary. This result shows that the friction of the waves on the bottom during storms has been sufficient to maintain a constant depth of from 20 feet to 21 feet in the desired direction, in spite of the average advance of 100 feet annually of the $3\frac{1}{2}$ -, 4-, and 5-fathom lines immediately facing the piers. Such an eminently favourable indication of the action of the waves beyond the pier-heads, in a north-easterly direction, during a period of fifteen years, is very encouraging for the future; and without venturing to affirm that the beneficial wave-action will be sufficient by itself to maintain the present depth over another long period of years, it may be said with confidence that the necessity to extend the piers seawards to assure the retention of the existing navigable depth, which has been gained by natural scour alone, without ever resorting to dredging, is less imminent to-day than it appeared to be fourteen years ago, when I had the honour to report to you specially on this interesting subject.

TABLE I.—ZONE I.—DEPOSIT AND SCOUR IN FRONT OF THE SULINA MOUTH OVER 612 ACRES, 1871-76, 1876-81 1881-86, and 1887-71.

Years.	No. of Years.	Average Deposit of whole Surface.	North.		South.		Totals.		Average Resulting Deposit.	Average total Deposit per Year.	Sediment in Suspension. Total.	Proportion of Deposit to Sediment carried.
			Deposit.	Scour.	Deposit.	Scour.	Deposit.	Scour.				
1871-1876	5	Feet. 1.29	Cub. yds. 114,530	Cub. yds. 114,530	Cub. yds. 1,456,395	Cub. yds. ..	Cub. yds. 1,456,395	Cub. yds. 114,530	Cub. yds. 1,341,865	Cub. yds. 298,373	Cub. yds. 291,279	Percent 10.65
1876-1881	5	0.47	554,108	..	..	69,999	554,108	69,999	484,109	96,822	110,822	3.12
1881-1886	5	0.41	599,787	..	..	171,204	599,787	171,204	428,583	85,717	119,957	4.13
1887-1891	15	2.17	1,153,895	114,530	1,456,395	241,203	2,610,290	355,733	2,254,557	150,304	174,019	5.68
1871-1891	14	2.69	480,072	..	2,304,307	..	2,784,379	..	2,784,379	198,884	198,894	6.55
	29	4.86	1,633,967	114,530	3,760,702	241,203	5,394,669	855,733	5,038,936	173,756	186,023	6.10
												5.70

TABLE II.—ZONES I, II, III IV and V.—SUMMARY OF DEPOSIT AND SCOUR OUTSIDE THE PIER-HEADS OVER AN AREA OF 2,691 acres. 1857-1886.
Total volume of sediment carried in suspension 88,452,300 cubic yards (see Table I).

Zone No.	Situation.	Deposit.	Scour.	Acres.	Deposit.	Scour.	Resulting Deposit.	Resulting Scour.	Proportion of Deposit to Sediment carried in suspension.	Proportion of Resulting Deposit to Sediment carried in suspension.
I.	Opposite to entrance	Feet. 4·86	Feet. ..	642	Cubic yards. 5,394,677	Cubic yards. 355,733	Cubic yards. 5,038,944	Cubic yards. ..	Per cent. 5·70	Per cent. 5·70
II.	South of Zone I.	4·80	..	675	6,698,970	1,478,346	5,220,624	..	7·57	5·90
III.	South of South Pier	4·97	..	247	2,152,093	175,831	1,976,262	..	2·43	2·23
IV.	North of Zone I.	0·56	..	316	1,280,788	967,701	313,087	..	1·45	0·35
V.	North of North Pier	..	..	1,910	15,526,528	2,977,611	12,548,917	..	17·55	14·18
		..	4·75	781	..	5,977,104	..	5,977,104	..	..
		..	..	2,691	15,526,528	8,954,715	6,571,813	..	..	7·43

III.—ABSTRACT OF THE COST OF THE SULINA PIERS FROM THE 31st OF DECEMBER, 1871, TO THE 31st OF DECEMBER, 1886 (15 YEARS).

—	North Pier.	South Pier.	Total.
	£	£	£
Prolongations	833	1,971	2,804
Consolidation of the prolongations	2,314	6,803	9,117
Maintenance	19,101	2,394	21,495
Total	22,248	11,168	33,416

IV.—SYNOPSIS OF METEOROLOGICAL OBSERVATIONS MADE DAILY AT SULINA, FROM 1872 TO 1886 INCLUSIVE.

Year.	Direction of Wind. Percentage.					Barometer at 32° Fahrenheit at sea-level.		Thermometer in the shade.		Rainfall.	River closed by Ice.
	N. to E. by N.	E. to S. by E.	S. to W. by S.	W. to N. by W.	Calm.	Max.	Min.	Max.	Min.		
						Inches.	Inches.	°	°		Days.
1872	21	20	15	9	35	30·71	29·45	98	7	11·00	66
1873	20	16	18	16	30	30·82	29·41	108	8	13·72	..
1874	13	6	9	10	62	30·78	29·27	95	-2	15·96	71
1875	32	11	21	30	6	30·74	29·28	96	-11	23·60	101
1876	36	15	25	21	3	30·71	29·21	90	-11	17·62	63
1877	36	15	21	23	5	30·70	29·36	86	3	19·60	..
1878	23	21	27	24	5	30·50	29·18	88	3	21·15	43
1879	31	17	26	23	3	30·73	29·04	91	-6	16·64	47
1880	31	18	23	25	3	30·79	29·54	91	-2	16·72	81
1881	36	18	16	26	4	30·70	29·23	90	7	21·39	48
1882	33	23	20	22	2	30·77	29·26	98	10	15·22	44
1883	43	22	16	17	2	30·71	29·12	95	5	13·74	64
1884	39	18	20	21	2	30·61	29·44	93	1	20·44	40
1885	42	22	17	17	2	30·85	29·35	95	1	15·23	43
1886	43	20	21	14	2	30·89	29·25	91	19	12·88	22
Average for 15 years.	32	17	20	20	11	..	..	..	..	16·99	49

V.—SYNOPSIS OF OBSERVATIONS CONCERNING THE DISCHARGE OF THE DANUBE, FROM 1872 TO 1886 INCLUSIVE.

Year.	Height of Surface of River above the Sea at Toulchea, 50 miles from Sulina.				Surface Velocity per minute at Sulina.		Volume of Water discharged, and Weight of Detritus carried in Suspension to the Black Sea.							
	Mean.		Minimum.		Maximum.		Volume of Water discharged per Second.		Weight of Detritus held in Suspension per Cubic Foot of Water.		Proportion of Weight of Detritus to Weight of Water.		Weight of Detritus discharged per annum.	
	Ft. Ins.		Ft. Ins.		Ft.		Cubic Feet.		Grains.		Grains.		Tons.	
	Ft.	Ins.	Ft.	Ins.	Ft.				Grains.	Minimum.	Maximum.	Minimum.	Maximum.	
1872	6	3	11	9	2	6	234,000	157	355	33	1	1	1	82,134,000
1873	4	7	9	3	1	0	181,000	111	364	12	1	1	1	51,543,000
1874	4	0	9	3	0	3	163,000	114	612	2	1	1	1	47,453,000
1875	5	8	10	4	1	2	215,000	95	717	9	1	1	1	47,399,000
1876	8	5	12	8	1	3	277,000	95	579	2½	1	1	1	57,888,000
1877	7	3	12	11	1	8	259,000	124	538	1½	1	1	1	66,474,000
1878	7	10	11	3	1	4	278,000	149	720	2	1	1	1	89,410,000
1879	8	9	14	5	2	1	297,000	67	177	2	1	1	1	44,064,000
1880	6	2	10	11	3	0	234,000	119	897	1	1	1	1	59,913,000
1881	8	7	13	0	3	9	297,000	141	331	11	1	1	1	92,421,000
1882	4	11	9	6	0	9	195,000	88	494	2	1	1	1	41,499,000
1883	7	11	12	7	2	5	276,000	128	480	5	1	1	1	82,377,000
1884	5	9	8	5	1	8	221,000	103	497	5	1	1	1	49,046,000
1885	5	5	8	3	2	0	211,000	98	316	8	1	1	1	44,510,000
1886	6	1	10	5	1	4	227,000	158	745	8	1	1	1	82,823,000
Average for 15 years	..		..		..		238,000	117	..	..	..	1	..	62,597,000
												3.739	..	

The weight of the detritus held in suspension is the result of experiments made regularly, ten times a month up to, and daily from, the 1st of June, 1876, on the effluent waters in mid-channel in the port of Sulina.

Experiments made during 1876 and 1877 on the weight of detritus held in suspension at the surface, and in depths of 15 feet and of 30 feet, gave the result that the average weight of detritus held in suspension is 36 per cent. greater than that observed at the surface.

(*Paper No. 2282.*)

"The Locomotive- and Rolling-Stock of the Bengal and North-Western Railway Company, Limited, India."

By JAMES RHIND, Assoc. M. Inst. C.E.

THE services of the Author were lent by the Government of India to the Bengal and North-Western Railway Company, Limited, to carry out the above work under Mr. Alexander Izat, M. Inst. C.E., Agent and Chief Engineer of the Railway, with whom he had been previously associated in doing similar work in India on the Kattiawar Railways. The Bengal and North-Western Railway extends from Sonapore, nearly opposite the city of Patna, in Bengal, where it is connected with the East Indian Railway by means of a ferry, to Bahraich in the North-West Provinces, a distance of 275 miles, with a branch of 20 miles in length going off at the 229th mile, from Mankapore to Nawabgunge, near to which it is connected with the Oudh and Rohilkund Railway by a bridge of boats in the fair weather, and a ferry during the monsoon season. The construction of temporary workshops began in May 1883, at Sonapore, these being intended to serve for the erection of the stock and plant, which was to go on simultaneously with the other construction works of the railway, and to carry on the work till the site of the permanent shops should be fixed and the shops erected. The buildings were three in number, of a section shown by Plate 5, where Fig. 1 represents the temporary machine-shop, and Fig. 2 the carriage-shed, each 204 feet long, with suitable stores and offices attached. A separate smith's shop and foundry was afterwards added of similar construction. Altogether the buildings cost, exclusive of fixing machinery, Rs. 19,000, and they still serve all the purposes of the railway. The pillars supporting the roof are stout "sal" wood poles, set in concrete, and the trusses, post-plates, and purlins are of "sal" scantling, the rafters being stout bamboos, on which are laid bamboo laths, and on these a double layer of tiles. The materials for their construction were all obtained in the district, and they were intended to be used as carriage- or coal-sheds when the permanent workshops were built. The advent of the rains, early in June, prevented rapid progress in their construction, and it was not till the end of September that

they were completed. In the meantime two locomotives and one hundred and fifty wagons had been received and erected, one-half of these being sent direct to Nawabgunge; and plate-laying was commenced from here and Sonapore simultaneously early in November. The wagons of these construction trains were specially fitted to carry the maximum load of materials, while giving facilities for loading and unloading quickly; thirty-five of them carrying a length of $1\frac{1}{2}$ mile of permanent way, and two such trains of materials were laid down daily from each end when the work was in full swing. In October of the same year, the erection of the carriage-stock may be said to have been begun, but it was not till November that sufficient materials were to hand and the work properly organized. At first labour was scarce and had to be imported from some distance, and temporary dwellings put up, while most of the men were unaccustomed to the work; but gradually they became more numerous, and with strict supervision a good quality of work was obtained. Task-work was adopted wherever possible, fully three-fourths of the work being so done. At the end of February 1884, forty-four carriage-vehicles were ready to be sent to Nawabgunge, it having in the meantime been determined to open the section of 75 miles from Nawabgunge to Bahraich first. The transit of these carriages was a work of considerable difficulty, as they had to be loaded in country boats, taken over the River Ganges, put on East Indian Railway wagons, and carried a distance of about 500 miles to Faizabad; here they were taken 3 miles over the trunk road, a bogie with yoke suitable for bullocks being substituted for the front pair of wheels of the vehicle, to the River Gogra, where they were again loaded up in country boats and finally landed on the north bank of that river at the terminus near Nawabgunge. Previous to this ten locomotives and one hundred wagons had been sent to Nawabgunge direct and erected there, most of them being ready for the opening of this portion of the line on the 30th of March, 1884. The construction of the remainder of the stock was in the meantime progressing satisfactorily; but the rains, beginning in June, put a stop to much of the out-door work, the shop accommodation being limited. At this time also the construction trains ceased to run, there being then but 8 miles of permanent way to be put down to join up the two rail-ends. The whole line was opened on the 13th of January, 1885, and the erection of the locomotive- and rolling-stock was then practically finished. In that and the following year two hundred covered goods-wagons were added to meet increased traffic, while two hundred bogie-wagons and twenty F-class locomotives

(Plate 5, Fig. 3) have since been got for extension of the railway to Napalgunj and Uska, and for additional traffic. The locomotive- and rolling-stock now on the railway, and their leading dimensions are illustrated by Plates 5 and 6 (see Appendix). In almost all cases the whole of the ironwork of the stock was received from England, and the woodwork, which is of the best Moulmein teak, was provided in India. Generally the stock is of the same type as that in use on Indian metre-gauge railways, and has been designed by Sir Alexander M. Rendel, K.C.I.E., M. Inst. C.E., who, along with Mr. H. Prince, M. Inst. C.E., is Consulting Engineer to the Company. In the Appendix is a statement of the cost of the English and Indian materials of the stock.

The materials for the vessels of the Ganges flotilla, consisting of two paddle-steamers, eight barges, and two landing-stages with approaches, were received between October 1884 and February 1885, and their construction was begun in November of the former year on the bank of the River Ganges, at Paleza Ghât; but previous to this a small screw- and a large paddle-launch had been built, and with them the passenger-service at the Ganges Ferry was first begun. The steel hulls of the vessels were fitted up in England, the parts marked and shipped along with their machinery to India, the woodwork generally being supplied in that country. As there was but little depth of water at the point on the river where the vessels had to be built, they were placed parallel to the stream, and launched broadside on; the ways consisted of three lines of metre-gauge permanent way, at an inclination of 1 in 20. Suitable cradles, having iron shoes to slide on the rails attached, were placed under the vessels, and they were hove off by means of their capstans and tackle attached to anchors in the river, check-ropes being fixed at bow and stern to allow them to move gently and evenly down the incline. All twelve vessels were launched at the end of May, 1884; the first steamer took up its station on the 1st of July, and the goods traffic, which had hitherto been carried in country boats, was transferred to the flats from the 1st of September, 1885. Each flat takes 80 tons; and as one trip can be made daily to and from the East Indian Railway terminus at Digha Ghât, a distance of $3\frac{1}{2}$ miles, the eight flats take 640 tons each way daily; but the traffic of the railway has developed so rapidly that, in the busy season, they are insufficient; and as there have been difficulties about labour for loading and unloading, and damage to goods from handling and exposure to the weather, it has been decided to ferry the stock over the river; suitable vessels with landing-stages, approaches, winding-engines,

&c., are now being erected in England, to designs prepared by Sir Alexander Rendel, and will be in operation next year. The present Flotilla will be fully occupied on the local ferry to Patna, and on the Gogra river-ferry during the rains. In addition to the construction of the rolling-stock and vessels, work to the value of Rs. 312,000 was done for other divisions of the railway and the public, the advantage of having a suitable place to do this being a great convenience and assistance in the construction of the railway.

The Paper is accompanied by numerous tracings, from which Plates 5 and 6 have been engraved.

APPENDIX.

BENGAL AND NORTH-WESTERN RAILWAY, INDIA.—COST OF LOCOMOTIVE-
AND ROLLING-STOCK, ETC.

Particulars.	Cost of English Material.	Erection Charges.	Total.	Remarks.
	Rs.	Rs.	Rs.	
E Class locomotive-engine and tender	16,260·0	559·0	16,819·0	
F Class locomotive-engine and tender (Plate 5, Fig. 3)	23,092·0	589·0	23,681·0	
O Class locomotive-engine and tender (Plate 5, Fig. 4)	17,536·0	545·0	18,081·0	
F Class locomotive-engine and tender (2nd lot)	2,272·0	2,500·0	4,772·0	{Converted from composite.
Saloon carriage (Plate 6, Fig. 1)	..	..	..	
Half-saloon carriage (Plate 6, Fig. 2)	2,272·0	2,500·0	4,772·0	Do.
Inspection carriage (Plate 6, Fig. 3)	2,272·0	2,250·0	4,522·0	Do.
Family carriage (Plate 6, Fig. 4)	2,272·0	2,095·0	4,367·0	
Composite carriage (Plate 6, Fig. 5)	1,254·0	1,111·0	2,365·0	
Third-class carriage (Plate 6, Fig. 6)	1,254·0	1,200·0	2,454·0	{Converted from third-class.
Intermediate third-class carriage	1,254·0	1,500·0	2,754·0	
Postal carriage	1,332·4	1,006·0	2,338·4	Do.
Brake-vans (Plate 6, Fig. 7)	1,332·4	1,200·0	2,532·4	{Converted from brake-van.
Road vans	1,332·4	1,500·0	2,832·4	
Horse-boxes (Plate 6, Fig. 8)	929·0	96·0	1,025·0	
Iron covered goods wagon (Plate 6, Fig. 9)	782·7	87·0	869·7	
Ditto Ditto (2nd lot)	963·0	30·0	993·0	
Iron low-sided wagon (Plate 6, Fig. 10)	2,014·0	87·0	2,101·0	
Iron covered goods bogie wagon (Plate 6, Fig. 11)				

(Paper No. 2245.)

"Notes on the Engineering Laboratories of the Massachusetts Institute of Technology."

By PROFESSOR GAETANO LANZA.

THE Mechanical Engineering Laboratory at the Massachusetts Institute of Technology was established during the school-year 1873-74, and received a considerable extension in October 1883; the Mechanical Laboratories or workshops were established in October 1876; and the Laboratory of Applied Mechanics was added in October 1881.

Of these the first mentioned was organized by Professor Channing Whitaker. The apparatus consisted of a complete outfit for making accurate boiler- and engine-tests, with both saturated and superheated steam. There were (*a*) two horizontal tubular boilers, each 4 feet in diameter and 12 feet long, containing fifty 3-inch tubes; (*b*) one small vertical tubular boiler, 3 feet in diameter and 7 feet high, containing fifty 2-inch tubes; (*c*) a cast-iron superheater; (*d*) an 8-inch by 24-inch Harris-Corliss engine with a brake on the fly-wheel; (*e*) a combined surface-condenser and calorimeter, with the necessary tanks and scales; (*f*) also a variety of accessory apparatus, as indicators, gauges, &c. From this laboratory there emanated an investigation into some special problems on cylinder-condensation made for Mr. George B. Dixwell.

This laboratory was further improved a year or two later by the addition of a mercury column, and considerable work was done in testing indicators, gauges, &c. It remained in substantially the same condition, being used for the instruction of the students until the summer of 1883; when the Author was called upon to take charge of the department, and he at once proceeded to extend the scope of the laboratory.

The mechanical laboratories or workshops were established by Professor J. D. Runkle, at that time President of the Institute. He conceived the idea by observing the work of the Imperial Technical School at Moscow, as exhibited at the Philadelphia Centennial Exhibition.

The Laboratory of Applied Mechanics was started with a Fairbanks' testing-machine of 50,000 lbs. capacity, which, besides being used for making tensile-tests of iron, wire, rope, &c., was also transformed in such a way as to enable full-sized beams to be tested for transverse strength and deflection, the allowable spans being any up to 25 feet. While this laboratory has since been much enlarged, both in space and in equipment, the work upon the transverse strength and deflection of full-sized timber beams, both under concentrated and distributed loads, and on the strength of framing joints, has, all along, been a feature of the work of the laboratory, and the fact has been ascertained that the actual breaking-strength of such timber beams is only about one-third or one-half as great as would be determined by calculations based upon the constants given by such authorities as Rankine and Laslett in England, or Trautwine, Rodman and Hatfield in America; the reason is that the constants which they give are based upon tests made upon small pieces, and hence are not applicable to cases which occur in actual construction. The resulting constants for full-sized beams, as determined in this laboratory, have been published in both countries, and are now generally accepted as correct wherever they are known.

The other machinery in this laboratory consists of—

(a) An Olsen testing-machine of 50,000 lbs. capacity for tension and compression.

(b) Apparatus for making tests on the transverse strength and deflections of full sized beams.

(c) A machine for testing the tensile-strength of mortar and cements.

(d) A Prony brake, and other machinery for making tests on the strength, twist, and deflection of shafts subjected to a combination of twisting and bending.

(e) A machine for testing the strength of ropes.

(f) The necessary accessory apparatus for measuring stretch, twist, deflection, &c.

The primary object of this laboratory is, of course, the instruction of the students; and it is believed that, besides the work in the recitation-room upon the strength of materials, they should be taught to do the testing themselves, to obtain accurate results, and to observe the behaviour of the materials when under stress.

While a considerable amount of investigation has been carried on in this laboratory, the experiments upon the transverse strength of timber, and on the strength of shafting under a combination of

twisting and bending forces, are probably the most original; though some work has been done upon the modulus of rupture of cast-iron in the form of window lintels, upon the behaviour of steel under stress at different temperatures, and upon the effects of different methods of holding wire rope, &c.

This laboratory work, as well as the recitation-room work in applied mechanics, is required not only of the students of mechanical engineering but also of those of civil engineering, of mining engineering, of architecture, of electrical engineering and of physics. Since October 1883, a much greater amount of space and a much more extensive equipment has been allotted to the Laboratory of Mechanical Engineering, making it really a laboratory of mechanical engineering, and not merely a steam laboratory. It now contains—

(a) An 80-HP. Porter-Allen engine, by which power is also furnished to the new building, and to the mining department.

(b) A 16-HP. Harris-Corliss engine, used almost exclusively for experimental purposes; this is furnished with two governors, one an automatic cut-off, and one a throttle governor, so arranged that either can be used. The automatic cut-off governor is so constructed that the speed of the engine can be varied at will.

The exhaust of each engine is connected with a surface condenser, and thence with a tank on scales; thus the water passing through the engines can be weighed.

(c) Three surface-condensers, one of which is arranged in sections so that the condensing-water can be made to traverse the length of the condenser once, twice, or three times, at the option of the experimenter.

(d) Machinery for determining the tension required in a belt to enable it to carry a given power at a given speed, with no more than a given amount of slip, whether the belt is horizontal or vertical, also so arranged as to make tests of rope transmission.

(e) Two friction-brakes, so constructed that a given amount of work can be put on either engine at will, and can be accurately measured; also two portable friction-brakes.

(f) Steam- and vacuum-pumps as follow: of the former, one Worthington, three Blake, one Deane, and one Knowles; of the latter, one Blake and one Deane air-pump, the Blake air-pump being connected with the condenser of the Porter-Allen engine.

(g) Three calorimeters.

(h) A transmission dynamometer.

(i) A 6-inch Swain turbine so arranged as to be run under a head of 15 feet; experiments being made on the power developed,

the efficiency, &c., under different gates; the power exerted being used up by a small brake on the shaft, and the water used being ascertained by passing it over a weir and measuring the head by means of a hook gauge.

- (k) Apparatus for testing injectors.
- (l) A Mack injector.
- (m) A Hancock inspirator.
- (n) A mercurial pressure-column.
- (o) A mercurial vacuum-column.
- (p) Apparatus for testing indicators under steam-pressure.
- (q) Apparatus for determining the quantity of steam issuing from a given orifice under a given difference of pressure.
- (r) Cotton machinery as follows: a Whitin card, an English drawing-frame, a Lowell speeder, a Lowell fly-frame, a Lowell ring-frame, a Mason mule, and a yard-tester.
- (s) Apparatus for calibrating weirs.
- (t) Apparatus for testing dynamometers.
- (u) An 8-HP. steam-engine used for setting valves, &c.
- (v) Four horizontal tubular boilers, and all the apparatus necessary for making evaporative tests.
- (w) A good supply of indicators, gauges, thermometers, anemometers, scales, and other accessory apparatus.
- (x) Also a Brown 40-HP. engine, a horizontal tubular boiler, a Deane pump, and a number of looms at the shops.

The work in this laboratory is required of the mechanical and also of the electrical engineering students.

Of the teachers, those who have duties in these laboratories are the professor in charge, two assistant professors, three instructors and three assistants.

As to the organization of such laboratories, the Author believes that there are three objects to be accomplished by them; namely, (1) to give the students practice in such experimental work as a mechanical engineer is constantly liable to be called upon to perform in the practice of his profession, as evaporative tests of steam-boilers, steam-engine tests, calorimetric tests, valve-setting, &c., teaching him to carry on his work with accuracy, and to take all proper precautions to avoid error; (2) To give the student an opportunity to carry on original investigation; (3) Another important function of such laboratories, which is entirely consistent with the other two, is that of taking up and carrying out systematic investigations of engineering problems, and this can be done in a laboratory, whereas it is only with very great difficulty that it can be done in a machine-shop, or a manufacturing establishment.

By publishing these results from time to time, the laboratory will serve to add gradually to the common stock of knowledge.

The Author recognizes very fully the incapacity of the student, as a rule, to originate and carry out research without aid from his teachers, but it is precisely because the necessary aid is given, and the necessary supervision exercised that a considerable amount of research has been accomplished in these laboratories. This is accomplished in two ways; (1) The regular laboratory experiments are so turned by the instructor as to make them form an element in some investigations, and the students take the observations and work up the results, the necessary amount of checking being done and the necessary supervision being exercised to insure correct results.

2. Original researches are actually carried on by the students in their graduating theses; some of them are, of course, more able to do this kind of work than others, but all are required to undertake original research, and only such supervision is exercised as is needed.

The number of important investigations which it is possible to take up and carry out is so very large that only a few can be undertaken in any one laboratory; hence it would be exceedingly desirable to establish a constant correspondence between all the laboratories of this kind, similar to the correspondence that exists between astronomical observatories the world over. By thus reporting to each other their results they would naturally come to so arrange their work as to play into each other's hands, and thus help along the cause of investigation.

As to tensile testing-machines, probably any inaccuracies in the machines made by good makers are very much less than the unavoidable differences in quality of the different specimens of the same material.

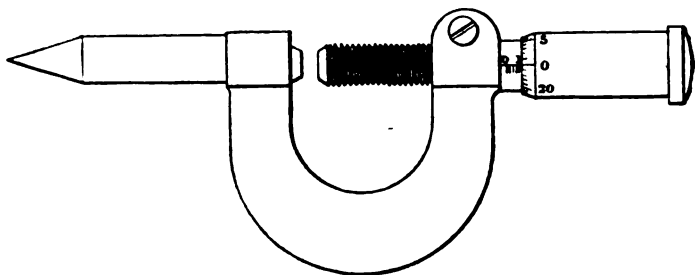
Where a large number of levers are used, as far as this applies to machines built on the principle of the platform scale, where the platform is supported on more than one lever, there is the advantage that the number of knife-edges supporting the load is greater, the pressure on each one is less, and the chances of cutting and thus changing the leverages, or of dulling the knife-edges, and thus impairing the sensitiveness of the machine, are less than when one single knife-edge has to support the entire load.

The use of the platform-scale principle is becoming prevalent among American makers of testing-machines. In the laboratory of the Massachusetts Institute there is one of this kind, made by Tinius Olsen, of Philadelphia, and the Author has no fault to find with it.

The Author is of opinion that any results on ultimate elongation, namely, on that part of the strain diagram that lies beyond the maximum load, unless very carefully interpreted, are liable to be misleading, as the ultimate elongation, and indeed the elongation in that part of the diagram which lies beyond the maximum load, will vary enormously according to the relative position held by the point of maximum contraction of area with reference to the points between which the stretch is measured; and it is impossible to predict whether this point of maximum contraction of area will fall within the other points, entirely outside of them, or partly within and partly outside.

The stretch below the elastic limit is a matter of great importance, and it should be measured with the greatest care and accuracy. Nevertheless, if that part of the test-piece that has the smallest section is as much as 10 or 12 inches long, the section

FIG. 1.



being 1 square inch or less, sufficient accuracy can be obtained for all ordinary purposes if the measuring instrument can be read to $\frac{1}{10,000}$ inch.

The measuring apparatus in use since 1881 consists of a Victor micrometer calliper graduated to $\frac{1}{1000}$ inch, which can easily be read to the $\frac{1}{10,000}$ inch by estimation. To the end of this calliper are attached extension-pieces of such lengths as may be needed in each case. The apparatus is shown by Fig. 1. As a rule shouldered specimens are not used; but whenever they are, the points between which the measurements are taken are on that part of the specimen that has the smallest section, and never on the shoulders. Having fixed these points, clamps are fastened on, which only touch the specimen at these points. The clamps for a square or flat specimen are shown in Fig. 2. The distances apart of these clamps are measured, the average distance

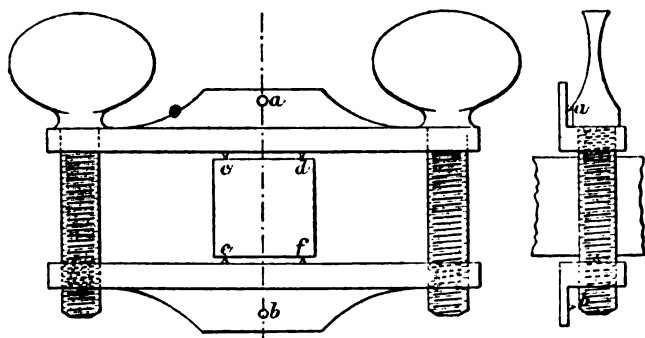
of two points being used with the flat, and of two or three points with the round specimen.

For compression-tests the important requisites are: (a) rigidity in the machine, (b) the possibility of so adjusting the bearing surfaces as to distribute the pressure uniformly over the specimen. This latter is accomplished by means of a ball-joint.

Cement-testing should be, of course, one feature of a laboratory of this kind, and should include compressive- and transverse-tests, in both of which the all-important caution to be observed, in order to insure correct results, is to have the force uniformly distributed over the cross-section of the specimen.

Next, in regard to transverse- and torsional-tests, the fact that transverse tests require proportionately less power than tensile- or compressive-tests renders it feasible to erect in a laboratory

FIG. 2.



sufficiently large and powerful apparatus to make the transverse- and shafting-tests on a practical scale. This is of special importance in transverse tests of timber.

With a testing-machine of 50,000 lbs. capacity it is an easy matter to make such alterations as to enable full-sized timber or iron beams to be tested both for strength and deflection, and it has been a source of surprise to the Author that this work should not (so far as he knows) have been undertaken in some other laboratory besides his own. As an example of the results that are obtained may be taken the test of a 9-inch by 14-inch yellow pine beam, 24 inches span, which had been selected by a builder as one of the best of his stock. It had an actual breaking-strength at the centre of 21,000 lbs., whereas the figures usually given would have made out its breaking-strength to be 42,000 lbs., and some experimenters

on small pieces would have called it 63,000 lbs. Similar results have been obtained with other kinds of timber.

Then again, the strength of such framing-joints as are used in buildings is constantly over-estimated by builders. A slight modification of the machine has rendered it possible to make tests of these full-size, and under such conditions as occur in every-day practice. While very little work of this kind has been done with rolled iron **I** beams, it ought to be done, and a machine of 50,000 lbs. capacity is all that is needed to break almost any of the **I** beams that are rolled, if advantage be taken of a span of 25 feet.

It is well known that the modulus of rupture of wrought-iron as shown by tests of small pieces is considerably in excess of the tensile-strength : whereas those tests that have been made with **I** beams of practical sizes have shown the modulus of rupture to be at least as low as the tensile-strength. But very little systematic work has been done on the subject.

In measuring deflections it is important that no part of the machine should be assumed to be fixed, but that the entire deflection apparatus should be attached to the beam under test itself. The method followed is to fix one micrometer screw on each side of the beam at the middle, and then to pass a fine piano wire over two steel pins, which are fixed in the beam at the middle of its depth, and directly over the supports; fastening this wire at the two ends beyond the steel pins, and keeping a constant tension by means of a spring-balance at one end. Evidently, then, the screw moves with the middle, and the wire with the ends of the beams, and the differences of readings of the screw, when it is just brought to touch the wire under two different loads on the beam, gives the deflection due to the difference of the loads, an average of the measurements on the two sides being taken to make up for warping, the position of the screw when it touches the wire being determined by means of a battery and a galvanometer placed in the circuit.

The question of the effect of time on the deflection of timber subjected to moderate transverse loads is another important subject of investigation, in regard to which what little has been done has shown that the modulus of elasticity to be used in computing deflections of timber beams should be considerably reduced from those usually given, if the beam is to be designed so that its deflection shall not exceed a certain given amount when time is taken into account.

The modulus of rupture of cast-iron is an old and vexed question, and although no longer used in building, cast-iron is still employed

places where its transverse-strength comes into lintels, in pulleys, gears, and gear-teeth; and, in connection with these uses, should be investigated. The question of window-lintels has been taken up.

The Author considers that, for a pure torsion test, that which Wöhler used for this purpose, consisting being divided into two equal halves, the two halves acting in opposite directions on the sides of the shaft, the twisting moment is uniformly applied in the form of a statical load, without any bending, of which no account is taken. On the other hand, a study of pure torsion is not the whole of the shafting problem. By far the greater number of shafts in use are subjected to a combination of twisting and bending, the former being due to the work transmitted, and the latter to the pulls of the belts, the pressure on the crank-pin, &c. Under certain circumstances the bending may have the greatest influence, while the twisting may be predominant in others, or their influence may be equally divided.

With a view to determine the behaviour of shafting under such a combination of conditions by actual experiment, suitable machinery had been put up in his laboratory. The principal points in the method of procedure were the following, viz. :—

1. The shaft under test is in motion, and transmitting an amount of power which is absorbed and accurately weighed by a Prony brake.
2. A transverse load is applied, which may be varied at the option of the experimenter, and which is weighed on a platform scale.
3. It is intended to adjust the proportion between the torsional and transverse loads, to correspond with the proportion between the power transmitted and the belt pulls sustained by a shaft in actual use.
4. Tests are made, not only of breaking-strength, but also the angle of twist and the deflection, under moderate loads, are measured.

In testing a shaft, the power is obtained from another shaft, and is transmitted to this test-shaft through a double Hooke's joint, and thence to a Prony brake through a double Hooke's joint on the opposite side. The power transmitted, and hence the twisting moment, is determined by means of weights at the end of the brake-lever, and the readings of a revolution counter. The boxes in which the experimental shaft runs rest upon a casting,

which, in its turn, rests upon the platform scale, and is separate and distinct from the rigid frame, which latter is firmly fastened to the floor of the laboratory. It follows that any weight resting upon the shaft under test, or the pulley which is on this shaft, is weighed directly on the scale; the flexibility furnished by the double Hooke's joints renders it possible to determine the weight on the shaft. The transverse load is applied by screws pressing down the boxes of an upper shaft, and causing a second pulley to press against the pulley above mentioned, and thus load the shaft transversely. In making an experiment upon breaking-strength, the transverse and the torsional loads are adjusted at the option of the experimenter, and then the shaft is run until fracture occurs. If the loads applied are too small to cause fracture they are increased, and the shaft is run until fracture occurs.

It has been shown by these tests that, in order to deduce any conclusions of value, the time occupied in breaking must be taken into account; thus the load required to break a shaft is much smaller if a week or ten days is allowed for it to run before breaking, than if it is to be broken in a short time, as one hour.

A description will now be given of the apparatus for measuring twist under moderate loads.¹ Two disks, made of brass, are placed on the shaft near its opposite ends respectively, each disk being in two pieces, so that they may be easily put on or removed from the shaft. At the centre of each disk is a boss, a little more than $1\frac{1}{2}$ inch in internal diameter, and carrying eight set screws (of which only one is pointed) for centering the disk and fitting it to any shaft of $1\frac{1}{2}$ inch diameter or less. The outside of the boss is turned down to form a bearing; on one disk for two wrought-iron arms, and on the other for one arm. One of the arms on the first disk carries a brass brush, pointed with platinum, which presses against the circumference of the disk as it revolves, and so also the arm on the second disk carries another brush, fixed in the same manner. The second arm on the first disk carries a tangent-screw, which presses against the arm with the brush. The arms are kept from revolving by suitable stops fixed in the frame, while the disks revolve under the brushes. The two brushes are insulated from the arms, but connected to each other by a wire, a battery and a telephone being placed in the circuit. The circumference of one of the disks and a portion of that of the other are of india-rubber, except that at one point in each circumference a thin piece of platinum is let into the india-rubber connected with the metallic

¹ *Engineering*. Vol. xliii. p. 26. Jan. 14, 1887.

portion of the disk, the circuit being completed through these pieces of platinum, the disks, and the shaft, so that if in the revolution the two brushes strike their respective pieces of platinum at the same instant, there is a current, and consequently a ticking in the telephone; whereas, if they do not strike it at the same instant, there is no current, and hence no sound in the telephone. The manner of using the apparatus is as follows: Start up the shaft with a very small load on the brake, screw the tangent-screw until a ticking occurs in the telephone, and measure (with a micrometer calliper) the distance apart of two metallic points, which are fixed in the arms for that purpose, at the same distance from the centre. Next put on the desired load on the brake, and again screw the tangent-screw until ticking occurs in the telephone, and measure the distance apart of the same two points. The difference of the angles corresponding to these two chords gives the angle of twist corresponding to the differences of the two loads on the brake.

In the work thus far described, and indeed in all the work of both laboratories, the endeavour is made to perform all the tests under such conditions as occur in every-day practice.

MECHANICAL ENGINEERING LABORATORY.

As a matter of course, tests of steam-boilers and steam-engines are subjects of prime importance in such a laboratory. Professor Lanza is of opinion that for any one boiler and any one engine there is a certain limit to the number of variations that can be introduced, and which cannot be exceeded without at the same time bringing in such proportions and conditions as would render the results obtained inapplicable to practice, and thus render any series of investigations made by the use of these variations of but little value when considered from an engineering point of view.

Hence in such a laboratory there should either be more than one engine, or else the range of variables should be so limited as to be consistent with the proper working of one engine. For instance, it seems hardly possible to obtain reliable results applicable to single engines by running a compound-engine, either with high-pressure steam in one cylinder alone, the other being out of action, or with high-pressure steam in both cylinders; hence, unless both a single- and a compound-engine can be afforded in a laboratory, tests on one kind only should be adopted.

BOILER TESTS.

In regard to tests of the evaporative power of steam-boilers, it is much more satisfactory to make the tests upon a reasonably large boiler than upon a small one ; and if a large boiler is used to its best advantage, it is absolutely necessary that the steam should be employed for some purpose other than running a small experimental engine in the laboratory, as this would require so small an amount of steam as to render it very uncertain how much steam was actually evaporated, and also to cause the boiler to work very inefficiently. Hence it is better to make tests of a boiler from which steam is used in large quantity, either for heating large buildings, or for running an engine which has a considerable amount of work to do, or both. If this is not the case, the steam must be allowed to escape somewhere, and this is annoying to the neighbours, and is not a condition met with in practice. Next, in regard to the method of making the test, Professor Lanza refers to two matters that he considers of great importance, the first being that of drawing fires at the beginning and end of the tests. Professor Lanza always insists with his students that the only way to make the test (usually a ten-hour test) accurate, is by drawing the fires at the beginning and end, and he would feel that otherwise he would be encouraging careless work in a matter where the greatest caution is needed to avoid any wrong conclusions, and where so many people are ready to delude themselves and to deceive others in claiming extraordinary evaporative efficiencies.

Another condition upon which he insists, and which many are in the habit of neglecting, is that, just before the beginning of the test, the boiler shall be running under its regular conditions, the pressure being approximately that which is to be carried throughout the test, and the brickwork all hot ; otherwise, starting with a cold boiler, and finishing with a hot one, an error is made equal to the amount of heat used to heat the brickwork, which may be considerable.

As to the feed-water, if a pump is used, it is a simple matter to weigh the water before it enters the pump, and to take its temperature by means of a thermometer in the feed-pipe, and just before it passes by the boiler check-valve. By observing this condition a heater may be used if desired, provided the heater does not leak, and that the temperature of the water is observed after it has left the heater.

If, on the other hand, an injector is used for feeding, the steam used

in the injector should be added to the feed-water, and this may be done with a good degree of approximation by taking the temperature of the suction and that of the delivery after it has passed the injector, and estimating from these the steam used per lb. of water fed; the temperature of the feed should, of course, be considered as that which it has just before entering the boiler. If an injector and a heater are both used, the delivery from the injector passing through a heater before entering the boiler, it will be necessary to take three temperatures, namely, that of the suction; that of the delivery before entering the heater, and that which it has after leaving the heater. It need not be added that a boiler-test, to be reliable, should be at least a ten-hour test.

PRIMING AND SUPERHEATING.

Another matter that requires attention is the amount of priming or superheating. If the boiler is a vertical one, or if its arrangement is such as to give rise to superheating, it will only be necessary to screw into the main steam-pipe, soon after it leaves the boiler, a thin metallic cup filled with either mercury or oil, and in this insert a thermometer to register the temperature of the steam. If, on the other hand, there is priming, it becomes necessary to use some form of calorimeter; but the Author has never had any trouble in using a Barrus continuous calorimeter of the old form.¹ The newer form² also works well. In regard to the difficulties that many persons have with calorimeter work in getting superheating when they know there is none, the Author believes that a great deal of trouble is due to working with a varying pressure; for, if the pressure varies by any considerable amount, a calorimeter becomes useless. The reason for this will be evident from the fact that, if the pressure decreases, then steam of a lower temperature comes in contact with a hotter pipe, and evaporation takes place, and hence less priming is shown than really exists, while the reverse is the case with an increasing pressure.

STEAM-ENGINE TESTS.

There are three principal ways of conducting steam-engine tests, as far as the determination of the amount of water actually used by the engine is concerned. The first is that which was

¹ Proceedings of the American Society of Mech. Eng., vol. vi. p. 296.

² *Ib.*, vol. vii. p. 178.

followed by Isherwood, and by a number of others, by which the water-consumption is ascertained by isolating the boiler from all uses except supplying the engine, and weighing the water fed into the boiler. In order to obtain reliable results by this method, several conditions must be observed as follows:—

(a) The engine must be of such size that a small error as to the height of the water-glass at the beginning and at the end shall not introduce a larger error into the results.

(b) The test must be of sufficient length, at least two or three hours, and better longer, for the same reason as stated in (a).

(c) If the steam from the boiler is used to supply the feed-pumps, the steam for this purpose must be carefully condensed and weighed, and its weight deducted from the water pumped into the boiler.

(d) If an injector is used, the steam must be determined as already explained and deducted.

The second method consists in determining the water-consumption by condensing the exhaust-steam, and either weighing it in a tank, or letting it flow over a weir and measuring the discharge. If a surface-condenser is used to condense the exhaust-steam, the condensed steam is kept entirely separate from the condensing-water; and hence, except in the case of very large engines, it can be weighed in a tank. In this case it is, of course, necessary to make sure that the condenser does not leak; but this can be readily determined by experiment. If a jet condenser is used, it will be necessary to determine the amount of condensing-water before it meets the exhaust steam, and also the amount of the mixture, the difference being the amount of condensed steam. In this case the quantities to be determined are generally so large as to preclude the possibility of determining them by direct weighing, and to necessitate the use of a weir. Another method that might be used is the discharge through an orifice, the discharge of this orifice under different heads having been first determined by experiment. By this second method of making a steam-engine test, trustworthy results can be obtained from a test of one hour and a half, or two hours, provided the power exerted is kept reasonably constant.

The third method is that used by Hirn, Hallauer, and others, in which the water-consumption is determined at both ends. This furnishes a check, and, if temperatures are taken, the heat-units can be checked. This method requires, of course, all the conditions of the first method, and also the precautions and measurements of the second.

As to which of these three methods should be followed in the laboratory: while it is a good plan (if the arrangements are such that it can be done on a scale that will give reliable results) to give the student some practice in either the first or the third method, nevertheless the second method, by dispensing with a consideration of the boiler, enables a much larger number of results to be obtained in the same time, and hence it seems to the Author to be the most suitable for the bulk of the laboratory work of this kind, both from the point of view of instructing the students, and also in order to advance the work of investigation. In these laboratories surface-condensers are used.

GENERAL REMARKS ON STEAM-ENGINE TESTS.

In regard to investigations by means of the steam-engine tests, the Author is of opinion that the most prominent question of the day in this connection, is upon the effect of the different conditions upon cylinder-condensation, and hence upon the economy of the engine; as there has been done upon the subject a very considerable amount of qualitative work, but very little quantitative. Now, to advance much in knowledge of the subject, it is necessary that systematic experiments should be made with a number of engines of different sizes and kinds; and the larger the number, and the greater the variety of the engines experimented upon, if the work is carefully and systematically done, the more will the knowledge of the subject be advanced.

TESTING INDICATORS AND GAUGES.

All the indicators and gauges of the laboratory should be carefully tested from time to time, and tables or curves of error made out. For this reason it is very necessary that such a laboratory should contain a mercurial pressure-column, a mercurial vacuum-column, and apparatus for testing indicators under steam-pressure. To trust to the makers' adjustments, or to the readings of so-called test-gauges, is not conducive to accurate results.

FRICTION-BRAKES.

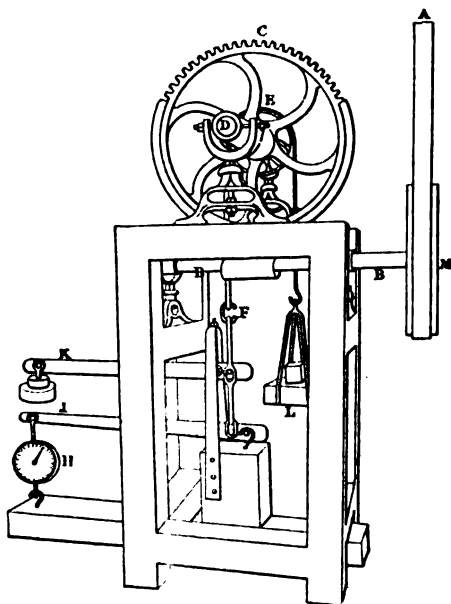
There are four friction-brakes in these laboratories, two fixed and two portable. In the two fixed ones a coil of pipe is cast in the rim of the wheel, through which the cooling water circulates in a continuous stream, thus securing a good circulation and conse-

quently economy of water. In one of the portable brakes the load is applied in a manner similar to that used by Wöhler in his torsion-machine already referred to, thus obtaining a real statical couple, and preventing any journal friction due to the weights in the scale pan.

TRANSMISSION OF POWER BY BELTING.

Inasmuch as the machinery used for this purpose is novel and peculiar to this laboratory, it will be described with some degree

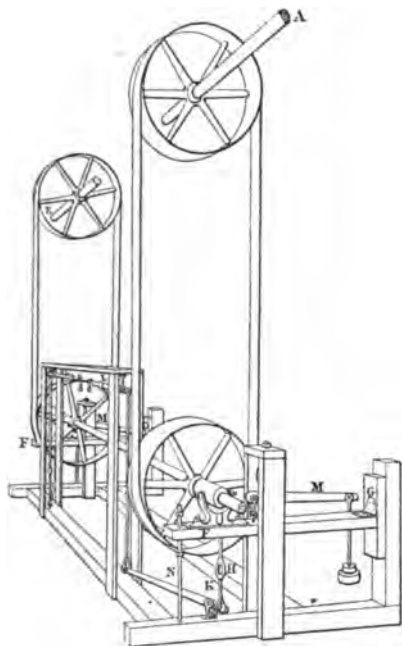
FIG. 3.



of fulness. There are in this connection three different sets of apparatus each accomplishing a different purpose. The object of the first is to determine experimentally the coefficient of friction from which to work up results by the ordinary friction theory of belting; but, inasmuch as it has been pointed out, by Professor Holman of the physical department of this Institute, that the coefficient of friction varies with every different speed of slip, the apparatus is arranged so as to vary the speed of slip at will, and to determine the coefficient of friction corresponding. The apparatus is shown in Fig. 3. By means of the belt A and pulley M, the worm-shaft B is set in motion, and, in its turn drives the worm

gear C, and hence the shaft D, and the pulley E, which is fixed to the shaft. The belt to be tested hangs over the pulley E, one end being attached by the link F to the lever I, the upward pull on this lever being registered by the dial H; at the other end of the belt is attached the scale-pan L, in which are put weights. The lever K is merely a counterweighting lever. During an experiment the motion is imparted in such a way as to turn the pulley E in a right-handed direction, the speed of a point on its circumference being the speed of slip of the pulley under the belt,

FIG. 4.



the right-hand side of the belt being the loose, and the left-hand side the tight side. The tension on the loose side T_2 is evidently the weight of the scale-pan L plus the weight in the scale-pan, while that on the tight side T_1 is read off on the dial H.

In using this machine, the speed of slip at which to run it is determined by running different belts in the laboratory with revolution counters on the shafts, thus ascertaining the speeds of slip in average running, finding the power used by one of the friction-brakes. The second set of apparatus is shown in Fig. 4. The power is transmitted from the shaft A to the shaft C, and thence to

the shaft E, by means of the two vertical belts; the shafts A and E being in one line, but not one and the same shaft. From the shaft E the power is transmitted by means of a belt to one of the friction-brakes, where it is weighed, and by adding to the power shown by the brake, the power required to drive the shaft E itself (determined by a dynamometer), the power is transmitted through each of the vertical belts; and, by means of a revolution counter attached to the shaft C, its number of revolutions is obtained, and hence the speed of the vertical belts, and hence by division the value of $T_1 - T_2$ for each one. The boxes in which the shaft C runs are fixed to the planks F F, and these are attached by the hinges G G to the two fixed uprights, the rod N being smaller than the hole in F through which it passes, and being merely used as a safety stop. The planks F F are therefore free to turn up and down about the hinges G G, the levers M M being counter-weighting levers. The desired tension is put upon the vertical belts after they are in position by means of the turnbuckles in the links H H, which are attached to the levers K K and thence to the scale-beams L L. Whenever the pulleys are of equal size, the weights on the scale-beams are the sums of the tension on the tight and loose sides, or $T_1 + T_2$; where the pulleys are not equal in size, it is only necessary to divide the weight shown on the scale-beam by the cosine of one-half the angle at which the belts are inclined to each other to obtain $T_1 + T_2$. Besides the above, a revolution counter is attached to the shaft A, one to C, and another to E, whence the slip of each belt is readily obtained, as well as its speed. Knowing the power transmitted, and the speed of the belt, $T_1 - T_2$ are easily found, and then from the scale-beam $T_1 + T_2$; hence T_1 and T_2 can be determined and the width of the belt required. Hence the following questions can be answered:—

1. In order to transmit a given power at a given speed of belt, what is the least value of $T_1 + T_2$ with which it can be transmitted without having the belt slip off?

What is the speed of slip which is obtained under these conditions, and what are the values of T_1 and T_2 ?

2. If a given power is to be transmitted with a given speed, and the speed of slip is not to exceed a given quantity, what is the value of $T_1 + T_2$ required for this purpose? and what are the values of T_1 and T_2 ?

Having answered these questions, the question of width of belt is to be determined by so fixing it that it shall be able to bear the required value of T_1 without injury and without losing its tightness.

With respect to the third set of apparatus, the Author will

merely say that it is of a similar nature to the second, only that it is arranged to have the belts under test in a horizontal instead of in a vertical position; and that it is also so arranged as to enable a much larger amount of stretch to be taken up, the reason being that the first use to which it will be devoted is to test the transmission of power by manilla and cotton rope running in grooved pulleys.

TEST OF STEAM-INJECTORS.

It might be well, perhaps, to mention the peculiarities in some apparatus which have been erected to test steam-injectors. The suction is drawn from a large calibrated tank, and the delivery, instead of being pumped into a boiler, is pumped into another tank on scales, where it is weighed, the resistance being produced by throttling, by means of a valve in the delivery-pipe. All the pressure and temperatures usual in such tests are observed, and also, in the case of the double injector, the temperature in the intermediate chamber.

THEORY OF STRUCTURES.

The only work of this kind as yet undertaken at the Massachusetts Institute of Technology, is the strength of such framing joints as are used in building, and these are tested full size.

No reference has, of course, been made to any electrical apparatus, for the electrical engineering laboratory belongs to another department, and is entirely distinct from any of the others.

This communication is accompanied by several diagrams, from which the Figs. in the text have been prepared.

(*Students' Paper, No. 221.*)

"Propelling-Machinery of Modern War-Ships."¹

By SIDNEY HERBERT WELLS, Wh.Sc., Stud. Inst. C.E.

IN this Paper the Author deals only with the propelling-machinery of modern war-ships of the heavily armoured turret and barbette type, having displacements varying from 7,000 to 10,000 tons, with a mean draught of water from 24 feet to 26 feet 9 inches; since he believes that a complete treatment of one class will be of more value than a consideration of all classes, which would necessarily be of an abbreviated and general character.

The designer of the machinery for such vessels has to contend with the following important influences, which do not affect the same problem when applied to merchant-ships; these are—that all the engines and boilers must be kept below the water-line; and that the space occupied by them, and their weight, must be as small as possible. Further, the machinery of a merchant-ship is designed to work with maximum efficiency at a continuous maximum power, while that of a war-vessel must be capable of efficient working not only at its maximum, but also when developing only from 10 per cent. to 15 per cent. of that power, under the conditions of ordinary service steaming.

It is the custom of the Admiralty, when inviting designs and tenders, to issue a specification in which numerous stipulations and restrictions do not leave the designer entirely free, although he can always submit alternative proposals subject to acceptance at his own risks. The following are the most important items specified:—

Centre lines of shafting, size of engine- and boiler-rooms, type of engine preferred, and material of chief parts, number of cylinders and boilers, steam-pressure, the total weight (not to be exceeded under penalties), and the indicated HP. under various conditions. Also approximately:—length of stroke of pistons, diameter of cylinders, air-pumps, and main shafts and rods, the

¹ This Paper was read at a meeting of the Students on the 4th of March, 1887, and was awarded a Miller Prize in the Session 1886-87.

number of revolutions per minute when indicating different powers, area of main bearings and guides, cooling surface in condensers, and fire-grate and heating surfaces in boilers.

The vessels having machinery of the type under consideration, whose steam-trials have been completed up to November 1886, are H.M.S.S. "Imperieuse," "Warspite," "Collingwood," "Rodney," "Howe," and "Benbow." They are all fitted with two complete and distinct sets of engines, driving twin-screws, and separated by the midship longitudinal watertight bulkhead. Each propeller turns outwards, the starboard propeller being right-handed, and the port propeller left-handed.

The engines work on the compound-expansion principle, with a maximum steam-pressure in the boilers of 90 lbs. per square inch, and with surface-condensers. Each set has three inverted vertical cylinders, one high-pressure and two low-pressure, their pistons working on three cranks at equal angles of 120° . The crank- and screw-shafting is hollow, and made of Whitworth compressed steel, the piston-rods, connecting-rods, and cross-heads are of Siemens-Martin, or other mild steel; the cylinders, slide-valves, and guides are of cast-iron, and the condensers and air-pumps of gun-metal; while for other parts, steel or wrought-iron is used in preference to cast-iron.

The old practice of casting the cylinders with projecting casings and flanges for bolting together, has only been followed in the engines of the "Warspite," the Admiralty having since insisted upon the complete separation of each cylinder with its attached parts, in order to allow of their easy working as independent engines. All similar working parts of each cylinder are made interchangeable, the amount of necessary spare gear being thereby reduced.

The engine-bearers of the ships are of box-girder form, and run longitudinally, parallel to the main-shafting; being connected by transverse frames at intervals. Upon these bearers the crank-bearing frames are bedded down and bolted, generally at their ends, either direct, or with hard-wood wedge-packing between; or the crank-frames are sometimes bolted to continuous fore and aft sole-plates, and thence with wood-packing to the ship-bearers. In other ships, the crank-bearing frames are bedded down for the whole of their length, direct to transverse ship-bearers; and while this makes a more solid and stronger arrangement, it necessitates the long and expensive task of working up the bearers by hand to a fair surface.

Between the forward and the aft cylinders of each set of

engines, and the corresponding athwartship bulkheads, strong angle- and plate-girders are built, known as "ramming-chocks," and the cylinders are stayed together by horizontal steel stays, one stay along each side. This is done to minimize the effect of strains experienced when the ship is ramming.

The maximum combined indicated HP. varies from 7,000 to 9,500, giving a proportion of indicated HP. per ton of displacement of from 0.95 to 1.09. The minimum and the maximum beam and water-draught is 61 feet and 68 feet 6 inches for the former, and 23 feet 9 inches and 26 feet 9 inches for the latter, respectively. These dimensions, when consideration is given to the questions of wing coal-bunkers, ship's double-bottom, and the diameter of the propellers, only allow of a breadth varying from 38 feet to 42 feet for both engine-rooms, and from 21 feet to 25 feet between the two lines of shafting, while the available height from the centre of the shafting to the water-line varies from 16 feet to 17 feet 6 inches. The best piston-stroke obtainable with these heights is from 3 feet 6 inches to 4 feet, with a connecting-rod length of twice the stroke.

The designs of the engines hereafter illustrated, cover all those of the vessels already named, and also of H.M.S.S. "Camperdown" and "Anson," not yet completed. Similar designs have been extensively fitted in war-vessels of foreign navies.

The following descriptions refer to one set of engines only; but when proportionate references are made, the power developed by both sets of engines is in all cases used.

The engines of design A, Plate 7, Figs. 1 and 2, have the high-pressure cylinder forward, with each slide-valve forward of its cylinder; that for the high-pressure cylinder being of the piston-valve type. Steam from the boilers enters the high-pressure valve-casing on the wing side, passing thence to the aft low-pressure cylinder, through a pipe along the same side, and to the mid low-pressure cylinder, through a pipe along the opposite side. Each cylinder rests upon four similar columns of double T section, bolted at their bases to crank-bearing frames resting upon fore and aft sole-plates. The columns, frames, and sole-plates are of cast-steel, and from their design give great strength with little weight. Each column has a cast-iron guide fastened to it, the piston-rods being bolted through horizontal cross-heads, having a double-faced guide-block at each end. There are two air-pumps, with attached hot wells, one on the midship side of the high-pressure cylinder, the other on the midship side of the aft low-pressure cylinder, their buckets being worked by rocking-beams and links off the cross-

heads, as shown in Plate 7, Fig. 2. A single condenser of rectangular section in plan is between these, all being as close to the columns as permissible. A double-cylinder reversing-engine is fixed between the condenser and the forward air-pump, the weigh-shaft, supported by plummer-blocks attached to the columns, being above it, with the reversing-wheel and starting-levers on the wing side of the high-pressure cylinder columns.

The engines of design B, Plate 8, Fig. 3, have the high-pressure cylinder between the two low-pressure cylinders, with its slide-valve athwartships, on the midship side, worked by a rocking-beam and links from eccentric-gear placed aft; the low-pressure slide-valves being between the high-pressure and the low-pressure cylinders. Steam from the boilers enters the high-pressure valve-casing from forward, passing thence through fore and aft pipes to the low-pressure cylinders. Each cylinder rests upon a heavy cast-iron inverted Y frame, on its midship side, and upon two turned steel columns about $6\frac{1}{2}$ inches in diameter on its wing side; these are bolted to cast-steel crank-bearing frames and sole-plates, as in design A. The piston-rods terminate in single-faced guide-blocks, which also form bearings for the gudgeons joining the connecting-rod forks, the shoe-plates working in cast-iron guides bolted to the Y frames. There are four air-pumps, placed two on the front of each low-pressure cylinder-frame, one on each side of the piston-rod, and worked by rods direct from the pistons, part of the frames forming hot-wells. There are two condensers of circular section in plan, on the midship side of, and central with, the low-pressure frames. The reversing-engine and hand reversing-wheel, are arranged on the midship side of the high-pressure frame, with the weigh-shaft above them, supported in brackets, connected to heavy cast-iron pipes of rectangular section, which join the tops of the Y frames. The starting-wheel and levers are fixed close to the forward high-pressure column, commanding a view of all the working parts.

The engines of design C, Plate 8, Fig. 4, have the same arrangement of cylinders, slide-valves, and pipes, as in design A, except that one pipe only is fitted, along the wing side, to convey the steam from the high-pressure to the low-pressure cylinders. Each cylinder rests upon four turned steel columns, about 7 inches in diameter, their bottom ends passing through cast-steel crank-bearing frames, and fastened with a key through column and frame, and with a nut and washer beneath; the frames are bedded

down for the whole of their length direct to transverse ship-bearers. There are also four diagonal stays, about $3\frac{1}{2}$ inches in diameter, to each cylinder, fixed fore and aft of the main columns, from the ends of the crank-frames to the opposite side of the cylinder base respectively. Each cylinder has two hollow cast-iron guides bolted to its under side, and stayed together at the bottom corners, the cross-head and guide-block being in one with attached shoe-plates. There are two air-pumps on the midship side of the low-pressure cylinders, worked by rocking-beams off the cross-heads as in design A, except that links are dispensed with at the air-pump end, the buckets having attached trunks with connecting-rods working on gudgeons inside them, and forming a bearing at their top ends round the cross-heads joining the rocking-beams. The air-pump discharge-pipe overboard for use when working with jet injection is vertical until it meets the main condenser discharge-pipe, a stop-valve being placed at their junction, so that when working with surface condensation this pipe serves as a hot-well, the pipe to the feed-tank leading away from below it. There is one condenser of elliptical section in plan, so placed, close up to the midship bulk-head, and central with the air-pumps, as to leave a passage between. The reversing-engine, wheel and starting-levers are on the midship side of the high-pressure cylinder columns, the weigh-shaft being on the wing side, supported in brackets attached to the cylinders.

Other engines, similar in construction to design A and in arrangement of cylinders to design B, were fitted with Joy's patent valve-gear. They are of 10,000 indicated HP. collectively, and the Author believes them to be the first of so large a power to which this gear has been applied for war-ships. Its use allows of the slide-valves being placed athwartships relatively to their cylinders, with a consequent saving of fore and aft space. The motion for working the valves is obtained from a point in the connecting-rods, the path of which is an ellipse, having its major axis equal in length to the stroke of the pistons, in this case 3 feet 3 inches, and transmitted through hanging levers and rocking-links to the valve-rods, a cast-steel horse-shoe shaped rocking-frame being used for reversing. It is not necessary here to enumerate the advantages claimed for the gear, nor can the Author give the result of its application to these engines, they being for Italian war-ships, yet unfinished. It has a larger number of working joints than the ordinary eccentric-gear, and although the weight is about equal and more evenly distributed,

the wear is greater and has a worse effect on the valve than the same amount of wear with the latter gear. It does not afford the same facilities for slide-setting, the accuracy of setting depending upon the exact agreement of the working parts with the drawings. The best distribution of steam at the top and the bottom can only be obtained with leads, almost equal, at a loss of the desirable feature of greater bottom lead. Its greatest practical objection is the way it blocks up the engine front, preventing ready access to the piston-rod gland and the top end of the connecting-rod.

The position of the high-pressure cylinder between the two low-pressure cylinders, while allowing of a more compact arrangement of slide-valves and steam-pipes than when the high-pressure cylinder is forward, necessitates larger low-pressure slide-jackets, to give sufficient receiver space, than with the long pipes of the latter position. The loss of pressure in the receiver is less, and the initial pressure in the low-pressure cylinders more uniform, while the work done in the high-pressure cylinder being generally greater than in either of the low-pressure ones, has only to be transmitted through one instead of two lengths of crank-shafting. On the other hand, as the boilers are usually forward of the engines, a longer main steam-pipe is required, and if, in addition to ensuring the above advantages, it is desired to save fore and aft space, to collect the valve-gears, and to gain light and short weigh-shafts, then it is necessary to have the high-pressure slide-valve athwartships; this entails the heavy rocking-lever and links of Fig. 3, Plate 8, in which the four working joints between the dummy-rod worked by the eccentrics and the slide-rod wear rapidly, and require constant attention to ensure efficient action of the valve.

In comparing the relative advantages of these designs, it should be remembered that the tests of efficiency, usually applied to the machinery of merchant-ships, do not always apply with the same force to war-ships. Without doubt the questions of accessibility to, and simplicity of, the working parts, the position of the starting and reversing wheels and levers, and the view of the cranks to be obtained from that position, are all of importance; but they are less so in a war-vessel with a large engine-room staff than in a merchant-ship with a smaller staff. For instance, with twin screw-engines, a door is always fitted in the midship bulk-head between the engine-rooms, and with a small staff it would be of great advantage if the starting- and reversing-gears of both sets of engines were so placed relatively to the door as to

allow of rapid and easy passage from one to the other; but for reasons already mentioned this advantage may in a war-vessel be more apparent than real. Comparing the three designs A, B and C on this point, the latter has its starting- and reversing-gear on the midship side of the high-pressure cylinder columns, close to the dividing bulkhead, and it is therefore especially well placed, and commands as good a view of the working parts as could be obtained from any part of the engines. Designs A and B, to ensure a good view of the cranks, have their gear on the wing side of the engine, and this necessitates travelling across both engine-rooms before reaching the opposite starting platform, the arrangement of floor-plates, permissible with the latter design, allowing this to be done with greater facility than with the former.

A fair comparison of the merits of the different arrangement of columns, guides and air-pumps cannot be well obtained if each point be considered separately, since the position of any one of them may settle that of the others, or indeed the whole design. It would not be possible, with the heavy cast-iron frames and light turned columns of design B, to obtain double guides, or the same position of air-pumps as in designs A and C. The chief advantage of the light columns, or "open fronts" of the former type, and of its position of air-pumps, is the good view obtainable from the wing side of all the working parts. This is possible in design C from either side of the engines, but the columns and light diagonal stays do not appear as likely to stand the strain of hard wear as well as the heavier columns and frames of designs A and B. The chief objectionable feature of the engines of design C is the arrangement of guides, which are about 21 inches wide, and completely hide and prevent ready access to the piston-rod gland and contiguous parts. The single guide of design B, while allowing plenty of bearing surface when running ahead, only gives about 50 per cent. of that area when running astern; consequently the pressure per square inch is increased to double, and is likely to cause heating; the guides are in a bad position for accessibility, the low-pressure ones being in addition blocked up by the air-pumps. The best arrangement for all points is that of design A, as it is not open to any of these objections. In every case the ahead guides are hollow, and when working have cold water circulated through them; the ahead shoe-plates are adjustable, and made of phosphor-bronze, or gun-metal and white-metal, the pressure per square inch varying from 80 to 95 lbs., taking the maximum pressure along the connecting-rods. The

bearing in the piston-rod end of design B, for the connecting-rod gudgeon, is open to serious objections ; it is difficult of access, and sufficient bearing-surface to reduce the pressure per square inch below 1,800 lbs. cannot be well obtained, while in the arrangement of designs A and C it is easy to have surfaces large enough to keep the pressure per square inch below 1,100 lbs. But, on the other hand, this plan allows of a simpler, lighter and less expensive connecting-rod than do the latter designs. The whole of the rod is forged in one piece, and the top end being bored and machined, a narrow slot is taken out of one web in each jaw ; the gudgeon is fitted in and gripped by screwing up a bolt and nut, passing through the divided webs and catching the gudgeon. The bottom end has a solid head and cap, with bushed brasses kept in position by set-screws. The rods of designs A and C have separate solid brasses and flat caps at both ends, and, apart from the advantage of the large area gained by the double top brasses, there is a liability with careless screwing up to throw all the strain upon one side, while the heavy bottom brasses have been known to crack across the crowns, and are liable to twist when heated. The diameter of the crank-pins varies from 17 inches to 18 inches, with a length of 1·12 time their diameter, the maximum pressure varying from 530 to 550 lbs. per square inch. The pins are lubricated by centrifugal lubricators, and white-metal is generally run into the brasses to form the bearing-surface.

The arrangement of air-pumps in design B, while saving the floor-space occupied by the pumps in designs A and C, is difficult of access for inspection and repair, and presents the objectionable feature of additional glands in the cylinder ends, while they also partly block up the main bearings ; their stroke and speed is of necessity equal to that of the engine-pistons, but in designs A and C any stroke may be obtained ; it is usually half that of the pistons, and the pumps are most favourably situated for access, although the rocking-beams and links are additional working parts needing attention. The pumps are all single-acting, and made large enough for efficient working when using jet injection ; the foot, delivery and bucket-valves are of the usual vulcanized india-rubber disk type, covering gratings.

The condensers are fitted with vertical tubes, about $\frac{3}{4}$ -inch in external diameter, made of solid drawn brass, and tinned inside and outside, the distance between the tube-plates being from 7 feet 6 inches to 8 feet. In the large condensers of designs A and C, one or more division-plates are fitted, water being circulated

outside the tubes by powerful centrifugal pumps, arranged as close to their work as possible. Auxiliary condensers are now being fitted to all ships, so that the main condensers have only to deal with the steam from the main engine; the usual cooling-surface is 2 square feet per indicated HP., but this has been reduced in the latest engines to 1.78 square foot. The Author believes that the necessity for using the jet-injection fittings has so seldom arisen, that they are being omitted from the present Admiralty specifications; this will permit of smaller air-pumps, and remove the chief cause of the demand for hot-well space. It may also be noted, that to allow of the air-pumps drawing from the bottom of the condenser, the arrangement of design B requires the condensers to be higher in the ship than in designs A and C, and this causes the centre of gravity of the whole machinery to be somewhat higher.

The method of bedding down the crank-bearing frames of design C, and their consequent form, necessitates longer columns for the same height of cylinder above the shaft centre, than when the frames are dropped in the middle as in designs A and B. The shortest column is obtained with the frame of design A, and this is the only one which allows of a square top brass and flat cap for the main bearings. In comparing the arrangements generally, designs A and C may be considered as practically similar; but the material points of difference between these and design B, while giving in the latter greater compactness, less weight, and a larger floor-space, and fewer, lighter, and simpler moving parts, do not ensure the same ready accessibility and good wearing qualities.

Plate 1, Fig. 8; is also arranged to show details of the cylinders and pistons. These present features of excellent design, and were first introduced in connection with the engines of design A; but they have now become generally adopted. The bottom ends of the cylinders are dished inwards, allowing of a greater distance between the stuffing-box and shaft-centre than with flat ends; and the covers, now made of cast-steel, are correspondingly dished outwards. Liners, made of Whitworth compressed steel, are shrunk in position, with an annular space of not less than 1 inch between the liner and cylinder-walls, for jacket-steam; the covers and bottom ends being hollow for the same purpose. A steam-pipe leads from the main stop-valve to the high-pressure cylinder jackets, and valves are fitted on the low-pressure cylinders to reduce their jacket-steam to half the boiler-pressure. The cylinder port-faces have double steam-ports to each end, and one large exhaust-port. Some makers fit separate port-faces, of a better wearing

metal, such as steel, fine-grained cast-iron, or phosphor-bronze; but this is objectionable owing to the large number of fixing-screws required to prevent warping, and their liability to work loose and cut the valve-face.

Piston valve-slides are sometimes fitted to the high-pressure cylinders, usually in connection with design A, and apart from the question of their use, to some extent fixing the relative position of the cylinders, and of the large space they occupy; they are better balanced, and move with less friction than flat valves. The body is of cast-iron, with phosphor-bronze bearing-rings, kept out by helical springs; steam from the boilers circulates above, below, and inside the valve, the exhaust-steam outside it, between the rings.

For the low-pressure cylinders, ordinary flat double-ported slide-valves are used (Plate 7, Fig. 2); the pressure on their backs is relieved by compensating rings, the space behind them being connected to the condenser. Counter-balance pistons are fitted to all valves, the space above the pistons being in communication with the condenser, or for high-pressure valves, to the low-pressure steam-pipes. The ratio of the high-pressure piston-area and cylinder-capacity to the low-pressure is as 1 to 4.05; expansion-valves to the high-pressure cylinders have only been fitted in the engines of the "Warspite." Lead is given to all valves, from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch at the top, with $\frac{1}{4}$ inch to $\frac{5}{16}$ more at the bottom, to counteract the extra momentum due to the weight of the pistons and the attached parts, the piston-speed amounting sometimes to 800 feet per minute. The low-pressure slide-valves are set permanently to cut-off at from 0.46 to 0.56 of the piston-stroke; but the cut-off can be varied, by linking up, in the high-pressure valves from 0.483 to 0.716 of the stroke, or other desired amount.

The pistons are made of cast-steel, and dished to correspond to the cylinder-ends; they have only a single thickness of metal for the body, and, with a weight of 35 per cent. less than the old cast-iron box type, do not show any appreciable deflection under a pressure of 180 lbs. per square inch, or twice their maximum working pressure. The bearing-rings are of cast-iron, kept in contact with the cylinder-walls by helical springs arranged in recesses in the piston (Plate 7, Fig. 2), or by some modern adaptation of the flat steel spring. The piston-rod is fastened to the piston by a coupling end, with bolts passing through both, the whole arrangement saving much cylinder space as compared with cast-iron pistons, with the rods fastened by a large nut.

In Plate 7, Fig. 2, and Plate 8, Fig. 3, two designs of valve-

gear as adopted in these engines are shown. The gear in Fig. 2, which is usually fitted to engines of design A, has a double plate-link, with the forked ends of the eccentric-rods outside, working round journals forged with the links; it possesses the great advantage of allowing the eccentric-rod working the valve to be brought in a line with the valve-rod, thus giving to the valve the full movement of the link. The end of the valve-rod has a bearing round the sliding-block, which moves between the two side-plates of the link, the drag-links being attached to outside journals at the link centre. In Plate 8, Fig. 3, the gear is shown as fitted to the engines of design B; the link is a solid bar of rectangular section with the eccentric-rods connected at each end, and moving through brass quadrants working in a heavy cast-iron guide-block, into which the valve-rod is fixed; here the eccentric-rod cannot be brought into the same line with the valve-rod, and does not give such a good movement to the valve. In the former gear the eccentric-rods are of circular section, with flanged bottom-ends bolted to gun-metal straps; but in the latter the rods are of rectangular section, and in one piece with the top-half of strap, the straps having brass linings. In both gears the sheaves are of cast-iron.

Steam- and hand-reversing gear, and turning-gear, is fitted to all engines, and starting-slides to all cylinders, which in matters of gauges, lubricators, drain-cocks, and other details are well supplied. Self-acting steam-traps are fitted, into which all jackets and valve-casings drain, and these are also brought into communication with steam-pipes for auxiliary engines, where water is likely to accumulate.

The propellers are a modification of the Griffith's type, with four blades, and made of gun-metal having a composition of 88 per cent. copper, 10 per cent. tin, and 2 per cent. zinc. The pitch varies from 17 feet 6 inches to 22 feet, with a diameter varying from 15 feet 6 inches to 18 feet, the ratio of pitch to diameter being from 0.972 to 1.26, with a total developed blade-surface of from 72.5 square feet to 88.3 square feet. The blades are made adjustable, so that the pitch may be varied over 4 feet.

The engine-rooms of H.M.S. "Benbow," from bulkhead to bulkhead, are 38 feet long, and 21 feet wide, with a height above the floor-plates to the deck of 18 feet 6 inches; in the "Warspite" and the "Imperieuse" these dimensions are 40 feet, 20 feet 3 inches, and 19 feet respectively, giving 14,763 cubic feet in the former and 15,390 cubic feet in the latter. The engines of these ships, measuring over the extreme points, occupy spaces of 7,888 cubic

feet and 8,160 cubic feet respectively; the remaining space is occupied by the main centrifugal engine and pump, the fire- and pumping-engine, the turning-engine, the feed-tank, a double-cylinder feed donkey-pump, and a similar bilge-pump, together with innumerable steam, exhaust, and water-pipes and valves, ventilating trunks, and other gear; and in addition, in one engine-room, the auxiliary condenser and combined centrifugal and air-pump. Efforts are always made to keep clear a passage-way all round the engines, but the limited space at disposal does not always permit of this being done, and, under most favourable conditions, the passage-way is sometimes reduced in width to less than 15 inches. It will thus be seen how much the war-ship engineer has to economize space in designing the propelling-machinery; the arrangement of design B is undoubtedly the best in a crowded engine-room, but it is questionable whether the means by which the compactness is gained is justified by the result.

If a greater distance could be obtained between the centre line of the engines and the wing coal-bunkers than the present 8 feet to 9 feet, an important improvement could be effected in arranging the engines, as the condensers could be placed on the wing side, and be equally efficient with half the length and complexity entailed in the present arrangement of piping. This would also permit of the starting- and reversing-gear being fixed on the midship bulkhead side, commanding a good view of the working parts; and in such a position many desirable improvements could be effected in the engines of design A, which are not now practicable by any arrangement. But this could not be done without cutting down the coal-bunker space, a proceeding which would not be permitted while coal is used as a protection against shot and shell; and one other objection to the plan is that it would bring the centre of gravity of each set of engines some 3 feet further from the centre of the ship, and, with the same degree of rolling, raise it higher than with the present arrangement.

The limits of this Paper will not permit of any detailed description of the boilers used in the ships named; their number, size and shape depends upon the arrangement of stokeholds, but they are all of what is known as the "Admiralty type." They are made of steel, and either circular or oval, with flat ends, and with two or three furnaces leading into the same, or into separate, combustion-chambers, with return tubes. A total firegrate surface is given of from 0.07 to 0.09 square foot per maximum I.H.P., with a heating-surface of from 2.13 square feet to 2.85 square feet.

The uptakes and funnels are made of steel with double casings, and have a total height above the firebars varying from 70 feet to 85 feet. In some ships the funnels are telescopic.

The general arrangement of piping and valves is very extensive and somewhat complicated. Either set of engines can take steam from any boiler or boilers; water can be pumped into any boiler from the feed-pump in either engine-room, or by the donkey seawater pump in any stokehold; and in all other ways everything possible is done, so that if necessary, some of the machinery may continue working, even when one or more of its important parts are disabled.

In addition to the auxiliary engines already mentioned, numerous others are fitted in connection with the propelling-machinery. These include fan-engines, and ash-raising engines, and bring up the auxiliary engines to thirty, this being the number fitted on H.M.S.S. "Imperieuse" and "Benbow," excluding the reversing and centrifugal engines. To these must be added steering, capstan, workshop, electric-lighting, air-compressing and hydraulic engines.

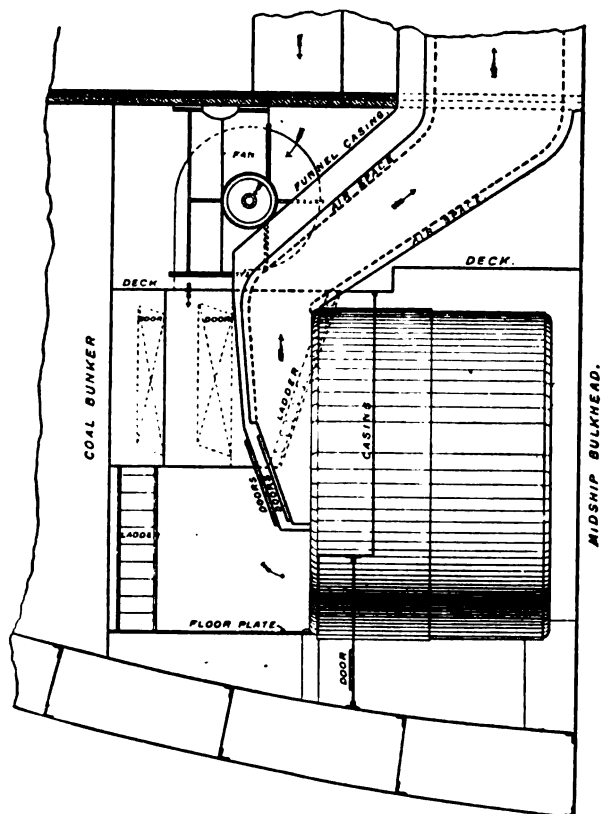
The large use of steel and of gun-metal in connection with the whole of the machinery, and especially in the main engines has resulted in a material reduction of weight. From Table I in the Appendix it will be seen that engines and boilers, constructed to work up to a maximum of 7,000 to 9,500 I.H.P., have been fitted in the ships named, to develop from 6·3 to 8·2 I.H.P. per ton of weight. But if the power indicated at the full-power trials be taken, as much as 10 I.H.P. has been obtained per ton of weight. It should be remembered in comparing these figures with those of earlier ships, that these weights include water in the boilers and condensers, all auxiliary engines and fittings, and all spare gear, the two last items having increased considerably in modern ships. Of the total weight, the boilers, with uptakes, funnels, and stokehold fittings, amount to about 0·54 or 0·58, leaving from 0·46 to 0·42 as the weight of the engines, propellers, shafting and spare gear. These figures give as much as 18·2 I.H.P. from each ton weight of engine, and 15 I.H.P. from each ton weight of boiler, taking the maximum designed power.

The most important improvement of recent years, in the machinery of war-ships of all classes, has been the application of forced draught to the boiler furnaces. This is effected by forcing air into the stokeholds, previously made air-tight, until the pressure there is increased above that of the atmosphere, sufficiently to balance a column of water varying from 1 inch to 2 inches in height

thereby obtaining greater power of combustion, and a corresponding quicker generation of steam.

Fig. 1 is a transverse section through one of the stokeholds of H.M.S. "Benbow," and serves to illustrate the extra fittings required for producing the draught, and the method of its application, as generally arranged in all ships of this class. The front boiler

FIG. 1.



TRANSVERSE SECTION THROUGH A STOKEHOLD OF H.M.S. "BENBOW."

Scale $\frac{1}{4}$ inch = 1 foot.

bearers are cemented air-tight where the boilers rest upon them, and are fitted with air-tight manhole doors. A casing is fixed about 2 feet 6 inches back from the boiler fronts, extending from the tops of the bearers, round all the boilers, and joining the uptakes above, and the transverse forward and aft bulkheads, at each end. An extra casing with air-tight doors, is fitted around

each smoke-box, extending to the *débris* deck above. In this deck are a number of air-tight doors, or flaps, arranged to be open when the boilers are working under ordinary atmospheric conditions. Two fan-engines are also fixed here, one over each end of the stokehold; the fans are revolved at from 400 to 500 revolutions per minute, and draw in air from the atmosphere outside the funnels, discharging it at their peripheries through the *débris* deck into the stokeholds below.

Admittance is gained to the stokeholds by means of air-locks, an arrangement of double air-tight doors, one door to be shut when the other is open; the pressure is recorded by water-gauges, one end of the column of water being in communication with the atmosphere, the other with the stokehold.

In the Appendix, Tables II and III, the results are given of the trials of the ships already mentioned with the boilers under natural draught, Table II, and with forced draught, Table III. It will be seen that the total power developed under the latter conditions amounted in some instances to nearly 50 per cent. more than under the former, and with approximately only the same steam-pressure in the boilers. This additional power is gained by increasing the revolutions, and generally produces a marked improvement in the speed of the ships; the great benefit of thus being able to hold in reserve so sure and easy a means of accelerating the steaming power of a war-vessel cannot be over-rated.

It should be noted that when the machinery of H.M.S.S. "Imperieuse" and "Warspite" was designed, it was not intended to apply forced draught to the boilers, its adoption not being decided upon in time to allow of any alteration being made to ensure its best effect. This will explain the smaller ratio of high-pressure to low-pressure cylinders of these ships, as compared to the later ones in which forced draught was considered in designing from the first.

As one result of the increased heat of combustion, brass boiler tubes have had to be abandoned, and iron tubes have been substituted at a loss of the constant efficiency gained by the better conducting power of the former. Considerable expense is attached to the extra fittings required, and some difficulty is experienced in obtaining efficient fan-engines, the high speed at which they require to be run not being maintained for any length of time without, in some cases, serious heating and knocking; while the inconvenience of working in the closed stokeholds may become painfully apparent owing to the plentiful circulation and deposition of coal-dust and

ashes, the eyes being specially affected. But the temperature is not so great as when under natural draught with open stokeholds by some 5° or 6° Fahrenheit, as with natural draught it is 92° to 98° , with forced draught 84° to 93° , and the fans are in a convenient position for readily supplying cool air, a useful acquisition with stokeholds badly placed for natural ventilation, and in hot climates. One defect of the system is shown in the rapid burning of fire-bars, and another will probably be seen in time, in the deterioration of the furnace crowns, as when the furnace doors are opened for stoking purposes there is a sudden rush of cold air upon the hot steel plates which must in time seriously affect them.

The general arrangement is to fit two fans over each stokehold near the ends, and when there are three boilers below, these fans are nearly central with the forward and aft boilers. As a consequence, the middle boiler gets considerably less air than the other two, and requires more attention to maintain regular firing, a defect which may be increased or diminished, according as the uptake converges to the funnel, or is central with it. There is a direct current of air to the furnaces of the end boilers, while the middle boiler furnaces only get the air due to their in-draught; and further, with three furnace boilers, the two upper furnaces being nearer to the fans than the bottom ones, get more air. That this is so is manifest by an examination of the firebars, after a trial of forced draught; but it could probably be avoided by employing three fans, or by throwing back the air from the fans by spread plates, against the coal bunker bulkhead.

The consumption of coal per indicated HP. per hour is invariably greater with forced than with natural draught, a mean for the former being 2.47 lbs., and for the latter 2.17 lbs. The difference is principally due to fuel carried up the chimney imperfectly consumed, and the greater heat of the escaping gases. The Author is not aware of any attempts having been made to register these, but the temperature above the boilers, outside the uptake casing, increases 60° to 75° Fahrenheit, or about 33 per cent. over that when under natural draught. With natural draught it is 110° to 155° , with forced draught 185° to 229° , and the temperature of the escaping gases probably varies in the same proportion.

No set of machinery of this class has yet been run at full power with forced draught for a longer time than four hours; this should be remembered when considering its advantages, as it is doubtful whether engines, designed and built to run at a certain power, could maintain for a much longer time a power exceeding this by more than 25 per cent. without a breakdown, although on the other

hand, the maximum designed power can be maintained more easily with forced draught than without it.

Some other plans of forced combustion have recently met with success in merchant-ships, notably the open stokehold system of Mr. James Howden; but these arrangements cannot be fairly compared with the Admiralty system, since the former are intended for permanent service with a view to economy of fuel, while the latter is only for occasional use, when increased power is necessary, and regardless of consumption.

In the Appendix, Table I, details are given of the machinery as fitted in the six ships already specially referred to; in Table II the results are given of the full-power trials under natural draught, and in Table III under full-power forced draught. For the purpose of comparison, similar particulars are given in Tables IV and V of the machinery and full-power trials of the sister ships "Edinburgh" and "Colossus," the last of the heavily armoured class in which the maximum boiler steam-pressure was only 60 lbs. per square inch.

In all cases, the machinery during the trials is in charge of the contractors, who also supply the stokers, the latter being men hired from outsiders, or lent by the Royal Naval Reserve. The indicator diagrams, and other results are taken by an Admiralty staff, not always large enough to perform the necessary duties with proper accuracy and care, especially in connection with the consumption of coal. Diagrams and other records are taken at the end of every half-hour, and worked out as the trials proceed.

The power developed by the engines, exceeds, in every instance, the designed or contracted power; under natural draught, the "Benbow" exceeded the other ships, by developing 1,157 HP., or more than 15 per cent. in excess of the contracted power; but under forced draught, the "Howe" was first, with 2,203 HP., or 23 per cent. over the contracted power. The highest power developed from each square foot of fire-grate, was 10·92 indicated HP., in the "Rodney" under natural draught, and 15·48 indicated HP. in the "Howe" under forced draught; and the maximum consumption of coal per indicated HP. per hour was 2·69 lbs. in the "Warspite" under the former, and 2·9 lbs. under the latter. But too much dependence should not be placed upon this result, the general arrangement in checking the coal being to weigh one out of every ten or fifteen buckets, and take the mean of the weighed buckets as an average for the whole number used, without observing any particular care to ensure uniformity. The boilers are always clean, and filled with clean sea-water, before commencing the trials,

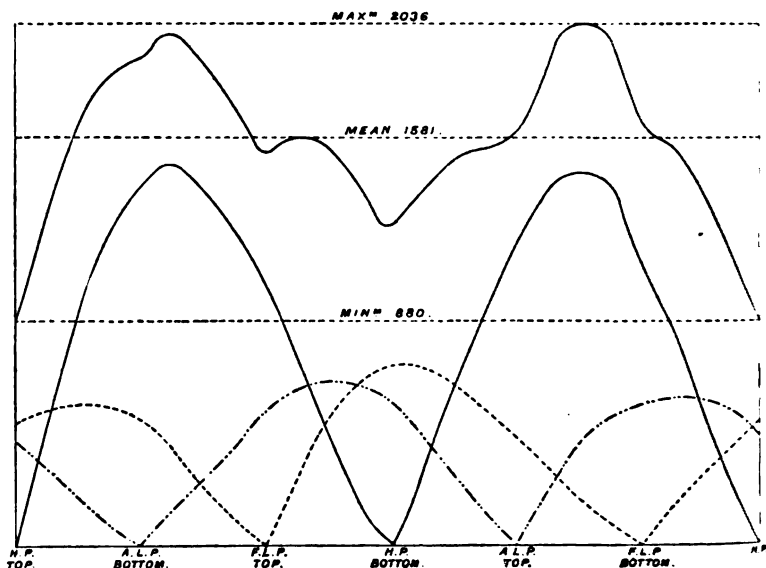
and hand-picked coal is used of good quality, while in other ways everything possible is done to ensure high results.

In no set of engines has the power developed been divided between the three cylinders in any equal manner, and this is especially noticeable in the trials under forced draught. With the machinery of the "Collingwood," "Rodney" and "Howe," the contractors seem to have adopted the plan of doing more than half the total work in the HP. cylinder alone, by maintaining a late cut-off and high mean pressure, while in the "Imperieuse," "Warspite" and "Benbow," the work is more equally distributed. In Figs. 2 and 3, are shown curves of twisting moments on the three cranks of one set of engines of H.M.S. "Benbow," at the end of the fourth half-hour of the natural-draught trial, and of H.M.S. "Rodney," at the end of the third half-hour of the forced-draught trial. The mean steam-pressures in the cylinders are taken from indicator diagrams, and the following Table shows the division of work:—

	"Benbow."	"Rodney."
Sequence of cranks { 1 Forward H.P. crank		Mid. H.P. crank
{ 2 Mid. L.P. "		Forward L.P. "
{ 3 Aft. L.P. "		Aft. L.P. "
Steam - pressure in boilers }	85 lbs.	86·5 lbs.
Vacuum in condensers }	25½ inches	27 inches
Revolutions per minute }	98	104·1
Mean-pressure in cylinders }	H.P. cylinder—45 lbs.	H.P. cylinder—60·5 lbs.
	Mid. L.P.—12·3 "	Forward L.P.—13·5 "
	Aft. L.P.—12·8 "	Aft. L.P.—12·95 "
I H.P. in cylinders }	H.P. cylinder—2,128·5	H.P. cylinder—3,039·7
	Mid. L.P.—1,178·2	Forward L.P.—1,373·6
	Aft. L.P.—1,234·4	Aft. L.P.—1,317·7
Total I.H.P. }	4,541·17	5,731
Total I.H.P. in one revolution }	46·33	55·05
Maximum strain on cranks }	1,700 inch-tons	2,036 inch-tons
Minimum strain on cranks }	875 "	880 "
Mean strain on cranks }	1,340 "	1,581 "

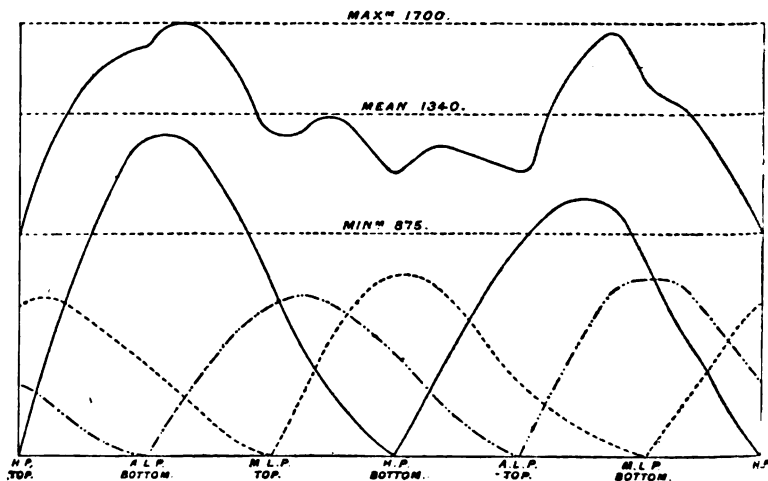
The crank diagrams are obtained by the formula. Twisting moment in inch-tons = $\frac{p \times a \times l \times \sin(\theta \times \phi)}{2,240 \cos \phi}$, where p = pressure per square inch in lbs. at a point corresponding to the angle θ of the crank, a = area of the cylinder, l = length of the crank in inches, and ϕ is the angle of obliquity of the connecting-rod, corresponding with the angle θ of the crank.

FIG. 2.



H.M.S. "RODNEY." STARBOARD ENGINES. FULL-POWER FORCED-DRAUGHT TRIAL.

FIG. 3.



H.M.S. "BENBOW." PORT ENGINES. FULL-POWER NATURAL-DRAUGHT TRIAL.
Scale for vertical ordinates $\frac{3}{4}$ -inch = 500 inch-tons.

In considering the division of work, it is important to note that an error in slide-setting may prevent an equal distribution of steam, and that alterations after the trial often result in improvement in this respect, as well as in others equally valuable.

It is unfortunate that no attempts can be made at comparison of relative efficiencies of these engines based on the consumption of fuel, as the figures given, even if accurate, only represent the total amount used, and not the proportion per indicated HP. developed in the main engine cylinders, owing to all auxiliary engines taking steam from the same boilers, and the impossibility of recording the work they do.

It will be seen from the result of the performances of the propellers that the "Collingwood" with propellers of 18 feet $10\frac{3}{4}$ inches pitch gave 1·26 per cent. negative slip, and 2·56 per cent. negative when the pitch was reduced to 17 feet 6 inches, while the "Edinburgh" and "Colossus" with similar propellers gave negative slips of 4·91 per cent. and 0·19 per cent. respectively; the "Rodney" and "Howe," also with similar propellers, gave respectively 14·76 per cent. and 17·63 per cent. positive slip.

The Author is not able to supply any exact information as to the cost of this machinery. Much depends upon the amount of ship-work undertaken by the contractors; while subsequent alterations and additions often largely add to the original contract price; but the sums paid to contractors according to recent "Blue-books" vary from £11 to £12 per indicated HP., that rate meaning sums of £107,000 or £108,000 for machinery such as fitted in the "Rodney," "Howe" and "Benbow." This price includes spare gear and erecting on board ship, but does not include extras.

The completion of the last of the "Admiral" class, H.M.S.S. "Camperdown" and "Anson," will probably mark the termination of the application of compound-engines working at a maximum boiler steam-pressure of 90 lbs. per square inch to war-ships, as described in this Paper; since H.M.S.S. "Surprise," "Renown," "Nile" and "Trafalgar" now building, are to be fitted with triple expansion-engines, working at a pressure of 135 lbs. per square inch; and if, with the increase of indicated HP. per ton of weight, this machinery is contracted to give, be ensured, the same economy and efficiency which has marked its extensive application to the merchant service, then will one more important improvement have been made in the successful development of modern war-ships.

The Paper is accompanied by several drawings from which Plates 1 and 2 and the Figs. in the text have been prepared

[A]

TABLE I.—continued.

	"Imperieuse."	"Warspite."	"Collingwood."	"Rodney" and "Howe."	"Benbow."
Cooling surface—condensers	16,000 sq. ft.	16,000 sq. ft.	14,000 sq. ft.	17,000 sq. ft.	17,000 sq. ft.
Proportion per I.H.P.	2 sq. ft.	2 sq. ft.	1.5 sq. ft.	1.789 sq. ft.	1.789 sq. ft.
Number of boilers.	12	12	..	12	12
" furnaces	36	36	..	36	36
Total grate surface	676 sq. ft.	687 sq. ft.	810 sq. ft.	756 sq. ft.	800 sq. ft.
Proportion per I.H.P.	0.0845 sq. ft.	0.0858 sq. ft.	0.09 sq. ft.	0.0795 sq. ft.	0.0812 sq. ft.
I.H.P. from each square foot	11.83	11.64	11.1	12.566	11.875
Total heating surface	22,800 sq. ft.	20,125 sq. ft.	20,448 sq. ft.	20,294 sq. ft.	20,244 sq. ft.
Proportion per I.H.P.	2.85 sq. ft.	2.515 sq. ft.	2.27 sq. ft.	2.136 sq. ft.	2.13 sq. ft.
I.H.P. from each square foot	0.35	0.39	0.44	0.468	0.469
Heating surface per square foot of grate	33.7 sq. ft.	29.15 sq. ft.	25.24 sq. ft.	26.84 sq. ft.	25.9 sq. ft.
Mean pitch of propellers.	22 ft. 04 in.	22 feet	17 ft. 6 ins.	19 ft. 6 ins.	19 ft. 6 ins.
Diameter of	18 " 2 "	18 "	18 feet	15 " 6 "	16 feet
Pitch	1.21	1.2	0.972	1.26	1.21
Diameter					
Total blade-surface for each propeller	87.04 sq. ft.	85 sq. ft.	88.3 sq. ft.	72.5 sq. ft.	76 sq. ft.

N.B.—The "Imperieuse" and "Warspite" are sister ships. The "Collingwood," "Rodney," "Howe" and "Benbow" are four of the six ships known as the "Admiral" class, the other two being the "Camperdown" and "Anson," which are being fitted with machinery of design A and a modification of design B respectively.

TABLE II.—FULL-POWER TRIALS WITH OPEN STROKEHOLDS. NATURAL DRAUGHT.

	"Warple."	"Collingwood."	"Rodney."	"Howe."	"Benbow."
Date of trial	May 3, 1886	May 1884	June 17, 1885	Jan. 12, 1886	Oct. 28, 1886
Length of trial	4 hours	3 hours	4 hours	4 hours	4 hours
Mean steam pressure in boilers	86·9 lbs.	90·25 lbs.	88·71 lbs.	88·25 lbs.	86 lbs.
" revolutions per minute {	80·23	89	93·87	94·3	95·14
" {Starboard	79·91	86·85	92·92	94·2	96·34
" {Port.	640·5	615·45	700·46	706·37	718·05
" piston speed in feet per minute	28·5 ins.	28·07 ins.	28·5 ins.	29·8 ins.	25·5 ins.
" vacuum in condensers	28·5 "	28·31 "	28·93 "	28·8 "	24·8 "
" {Starboard	37·7 lbs.	49·93 lbs.	45·61 lbs.	43·5 ins.	46·84 lbs.
" {Starboard HP.	11·05 "	12·79 "	11·74 "	9·86 "	11·49 "
" pressure in cylinders	43·29 "	50·2 "	43·44 "	44·4 "	43·63 "
" {Port HP.	9·46 "	12·96 "	11·5 "	10·5 "	12·43 "
" {LP.	1,742·06	2,001·83	2,068·46	1,979·85	2,150·9
" {Starboard HP.	2,000·98	2,076·98	2,135·53	1,817·68	2,137·05
" I.H.P. in cylinders	1,992·39	1,964·04	1,948·22	2,018·67	2,028·76
" {Port HP.	1,706·73	2,053·75	2,089·00	1,878·37	2,341·04
" {2 LP.	3,743·04	4,078·81	4,221·99	3,797·53	4,287·95
Total mean L.H.P.	3,689·12	4,017·79	4,037·22	3,897·04	4,369·8
" collective I.H.P.	7,442·16	8,096·6	8,259·21	7,694·57	8,657·7
Consumption of coal per I.H.P. per hour	2·69 lbs.	2·16 lbs.	1·93 lbs.	1·99 lbs.	2·61 lbs.
" " per sq. ft. of fire-grate per hour	29·24 "	21·58 "	21·08 "	20·35 "	28·25 "
I.H.P. from each sq. ft. of fire-grate used	10·83	9·99	10·92	10·17	10·82
" " heating-surface used	0·869	0·896	0·407	0·378	0·427
Pitch of propellers	22 ft. 3 ins.	18 ft. 10½ ins.	19 ft. 6 ins.	19 ft. 5 ins.	19 ft. 6 ins.
Mean speed of ship in knots per hour	15·5	16·602	not taken	15·872	16·5
" slip per cent.	11·83	1·26 negative	—	12·1	10·44

TABLE III.—FULL POWER TRIALS WITH CLOSED STOREHOLDS—FORCED DRAUGHT.

	"Imperieuse."	"Waspitoe."	"Collingwood."	"Rodney."	"Howe."	"Benbow."
Date of Trial.	Oct. 14, 1885	May 5, 1886	May, 1884	June 13, 1885	Jan. 14, 1886	Oct. 30, 1886
Length of Trial.	4 hours	3 hours	3 hours	4 hours	4 hours	4 hours
Mean air-pressure in storeholds	1.1 in.	1 inch.	93.75 lbs.	1.4 in.	2.05 ins.	1.34 in.
Mean steam-pressure in boilers	86.5 lbs.	92.57 lbs.	95.4	93.06 lbs.	89.21 lbs.	89.6 lbs.
Mean revolutions per minute	86.85	87.43	94.84	104	106.9	100.99
Mean piston speed in feet per minute	87.67	87.13	94.84	103	106.3	102.44
Mean vacuum in condensers	698	698.24	695.7	776.25	799.5	782.86
Mean pressure in cylinders.	27.25 ins.	28.1 ins.	28 ins.	27.5 ins.	29.3 ins.	28.4 ins.
	28 ins.	28.1 ins.	27.9 ins.	28 ins.	27.8 "	27.1 "
	44.48 lbs.	46.14 lbs.	56.93 lbs.	59.75 lbs.	59.1 lbs.	44.08 lbs.
	13.86 "	14.47 "	14.08 "	12.83 "	14 lbs.	16.52 "
	44.6 "	47.19 "	55.68 "	60.10 "	59 "	44.08 "
	14.04 "	13.69 "	13.17 "	12.78 "	13 "	17.26 "
	2,224.9	2,323.37	2,446.56	2,999.2	3,049.3	2,148.6
Mean I.H.P. in cylinders	2,717.7	2,856.28	2,450.7	2,608.5	2,925.75	3,261.5
	2,251.9	2,368.08	2,379.0	2,987.8	3,027.09	1,985.16
	2,779.0	2,692.9	2,280.5	2,573.3	2,701.52	3,456.54
	4,942.6	5,179.65	4,897.26	5,607.7	5,975.08	5,410.1
Total mean I.H.P.	5,030.9	5,060.98	4,659.5	5,561.1	5,728.61	5,441.7
Total mean collective I.H.P.	9,973.5	10,240.63	9,556.76	11,188.8	11,709.69	10,851.8
Consumption of coal per I.H.P. per hour	2.3 lbs.	2.9 lbs.	2.71 lbs.	2.2 lbs.	2.17 lbs.	2.8 lbs.
Consumption of coal per sq. ft. of fire-grate per hour	33.9 "	43.2 "	31.9 "	32.5 "	33.5 "	39.29 "
I.H.P. from each sq. ft. of fire-grate used.	14.7	14.9	11.8	14.7	15.48 "	13.56
" " heating surface used.	0.435	0.508	0.467	0.55	0.576	0.596
Pitch of propellers	22 ft. 0.4 ins.	22 ft. 3 ins.	17 ft. 6 ins.	19 ft. 6 ins.	19 ft. 5 ins.	19 ft. 6 ins.
Mean speed of ship in knots per hour.	17.213	17.25	16.844	16.9	16.932	17.495
Mean slip per cent.	10.37	9.98	2.56 negative	14.76	17.63	10.61

TABLE IV.—PARTICULARS OF MACHINERY.

	"Colossus."	"Edinburgh."
Displacement of ship	7,750 tons	7,750 tons
Mean draught of water	22 ft. 9 ins.	22 ft. 9 ins.
I.H.P.	6,000	6,000
I.H.P. per ton of displacement	0·774	0·774
Type of engines	Design A	Design B
Total weight	1,100 tons	..
I.H.P. per ton of weight	5·454	..
Maximum steam-pressure in boilers	60 lbs.	60 lbs.
Diameter of 2 H.P. cylinders	58 ins.	58 ins.
" " 4 L.P. "	74 ins.	75 "
Stroke of pistons	3 ft. 3 ins.	3 ft. 6 ins.
Total H.P. piston area	5,284·2 sq. ins.	5,284·2 sq. ins.
" L.P. "	17,203·6 " "	17,672 " "
" H.P. cylinder capacity	119·26 cub. ft.	128·4 cub. ft.
" L.P. " " "	388·27 " "	436·4 " "
L.P. areas or capacities = ...	3·25	3·4
H.P. areas or capacities		
H.P. piston constant	0·52041336	0·560445
L.P. " " "	0·8471469	0·937130
Cooling-surface in condensers	12,000 sq. ft.	12,000 sq. ft.
Proportion per I.H.P.	2 sq. ft.	2 sq. ft.
Number of boilers	10	10
" " furnaces	28	28
Total grate surface	645 sq. ft.	665 sq. ft.
Proportion per I.H.P.	0·1075 " "	0·118 " "
I.H.P. from each square foot	9·302	9·02
Total heating-surface	17,507 sq. ft.	18,750 sq. ft.
Proportion per I.H.P.	2·907 " "	3·12 " "
I.H.P. from each square foot	0·342	0·32
Heating-surface per square foot of grate	27·14 sq. ft.	28·19
Mean pitch of propellers	18 ft. 7½ ins.	18 ft. 6 ins.
Diameter of propellers	17 " 8½ "	17 " 6 "
Pitch		
Diameter = ...	1·05	1·057
Total blade-surface in one propeller	80 sq. ft.	74 sq. ft.

NOTE:—The engines for these ships, although similar to designs A and B, as in Figs. 1, 2, and 3, are not coincident with them, as they have the old cast-iron columns and bed-plates and condensers.

TABLE V.—FULL-POWER TRIALS—OPEN STOKEHOLDS.

	"Colossus."	"Edinburgh."
Date of trial	Jan. 10, 1884	Feb. 6, 1884
Length of trial	6 hours	6 hours
Mean steam-pressure in boilers	61·52 lbs.	62 lbs.
Mean revolutions per minute .	Starboard . . Port . . .	90·02 89·4
Mean piston speed in feet per minute	584·74	629·3
Mean vacuum in condensers .	Starboard . . Port . . .	27·7 ins. mean
Mean pressure in cylinders .	Starboard H.P. " L.P. Port H.P. . . " L.P. . .	27·5 ins. mean
Mean I.H.P. in cylinders . . .	Starboard H.P. " 2 L.P. Port H.P. . . " 2 L.P. . .	40·24 lbs. 12·11 " 40·92 " 11·97 "
Total mean I.H.P.	Starboard . . Port . . .	38·24 lbs. 10·84 " 36·67 " 11·29 "
Total mean collective I.H.P.	7,486·33	7,679·1
Total maximum I.H.P. recorded	7,870·09	8,002·14
Consumption of coal per I.H.P. per hour	2·55 lbs.	Not published
Consumption of coal per sq. ft. of fire-grate per hour	29·6 "	..
I.H.P. from each sq. ft. of fire-grate used	11·6	11·54
" " " heating-surface used	0·427	0·409
Pitch of propellers	18 ft. 7½ ins.	18 ft. 6 ins.
Mean speed of ship in knots per hour	16·53	17·2
Mean slip per cent.	0·19 negative	4·91 negative

(Paper No. 2246.)

**"Note on the Government Testing-Works at Malines,
Belgium."**

By E. J. ROUSSEL.

THE great importance of the development of the network of Belgian railways of late years has necessitated the creation of a complete service of control and of experiments, for the reception of the material and the stores necessary for its working. It must likewise be considered that, owing to the terms of the Belgian law in regard to the accounts, whereby all supplies must be obtained by public contract, recourse can be had to direct purchases or to restricted contracts only in altogether exceptional circumstances. Under these conditions it can readily be understood how important it is that the numerous stores when presented for acceptance should undergo a minute examination. It is this which has rendered indispensable the establishment of the engineering laboratories about to be described. It must further be added that experiments are required for the same object by the Administrations of Ports, Telegraphs and Marine, Bridges and Roads, and Mines. Besides the trials made for the reception of the stores intended for these different administrations, the service is likewise charged with the study of a great number of special questions necessitating experiments of all kinds. Companies foreign to the different services of the State, as well as private persons, can demand its aid, which is regulated by the ministerial resolution of the 3rd of June, 1882, as follows:—

The service of trials that the Author has the honour to direct comprises three different sections:—1. Chemical tests; 2. Mechanical tests; 3. Tests of combustibles.

1. *Chemical Tests.*—In the chemical laboratory are carried out all the analyses necessary for the control of the quality of the products of such different varieties as are employed by the various services of the Ministry of Railways, Ports, Telegraphs, and Marine. The number of chemical analyses made with this object in 1886 was 6,964. This laboratory is thus called upon to give

information of the most varied character, such as photometric trials of the different systems of lighting, analyses of water, of cast-iron, of steel, of bronze, of lime, of cements, and of colours, etc. It examines industrial products with a view to their nature and their commercial value, in order to determine the place that they should occupy in the general classification of merchandize. It makes tests of the conditions of transport of inflammable materials, explosive or subject to deterioration. In a word, it undertakes all the technical researches that are allied to chemistry. The multiplicity of the tests of all kinds, and the rapidity with which they must be made to meet the wants of the service, have necessitated the establishment of a laboratory which, by its sufficiently large arrangements and apparatus of all kinds, can satisfy all requirements.

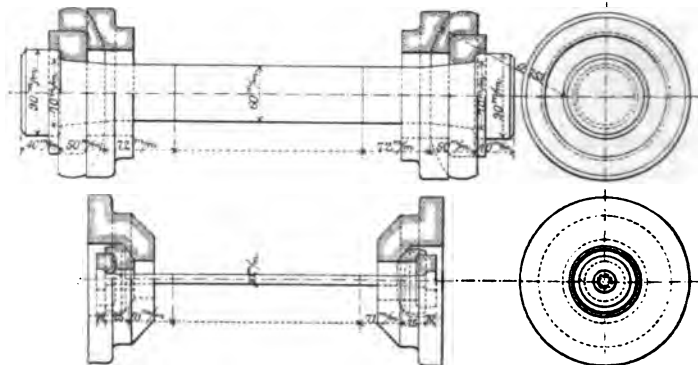
2. *Mechanical Trials.*— These trials affect materials before entering into construction, such as sheet-iron, different kinds of iron, rails, bronze, wood, stones, bricks, &c., and certain made-up articles (chains, ties, cables, iron sleepers, springs, tires, axles, &c.). Besides, certain trials of precision are made in view of special studies (determination of the coefficient of elasticity and of the resistance to the elastic limit, &c.). In the course of 1886 there were carried out 54,372 tests of all kinds. The various apparatus for conducting these tests include a ram with a series of monkeys for the trial by shock of tires, axles, rails, &c.; a spring weighing-machine on the Buckton system; an apparatus to bend sheet-iron cold; a dynamometer to test cloths, ropes, iron and steel wire up to 1,540 lbs. (750 kilograms); a dynamometer to test sheetings, string, and thread up to 154 lbs. (70 kilograms); a dynamometer to test papers and fine thread up to 77 lbs. (35 kilograms); two special machines to ascertain the strength of cements; a full-size machine for testing oil on the Thurston system; a complete apparatus for the projection of luminous rays for the study of fractures; a traction-machine of a power of 60 tons, specially intended for the trial of chains of all kinds, hooks and coupling-screws, in which the experiments can be made on a length of 23 feet (7 metres); a 500-ton testing-machine on Kirkaldy's system; Colonel Rosset's spiral multiplying quadrant; Professor Bauschinger's mirror apparatus.¹ The Author uses for tensile-experiments a mode of attachment in some respects analogous to that described by Professor Kennedy.² While it accomplishes the same object, it

¹ Minutes of Proceedings Inst. C.E. vol. lxxxviii. p. 23.

² *Ibid.* p. 35.

renders the trial of tests more easy of execution. In Fig. 1, round bars are shown, but this system serves equally well for flat test-objects. For compression-tests the Author has applied the

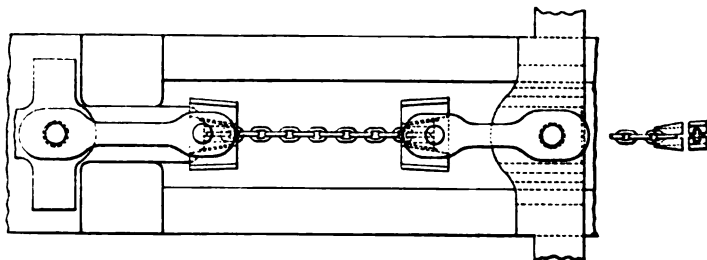
FIG. 1.



spherical joint to the face, between which the cylinders or the test-prisms are placed. In this manner the least want of parallelism of the faces of the test-piece which are subjected to the thrust of compression is corrected. This apparatus has been constructed by Mr. C. Klebe of Munich.

For testing chains the Author has constructed special wedges, as shown by Fig. 2. A link at each extremity of a portion of

FIG. 2.



chain subjected to tension is pressed over almost all its periphery, and the neighbouring links pass freely. With five sets of wedges of different sizes, chains of all dimensions can be tested.

3. *Trials of Combustibles.*—The coals employed in the locomotives of the Belgian State Railways are semi-bituminous, containing 12 to 14 per cent. of volatile matters. Non-bituminous coal is also used mixed with a certain quantity of bituminous coal

for binding it, so as to obtain a combustible which is not carried away in the smoke-box by the draught of the locomotive.

Different qualities of these coals are furnished by public contract, which are used according to the various needs of the service. The following are the requirements exacted for the supply :—

NON-BITUMINOUS and SEMI-BITUMINOUS COAL.

Designation.	Quantity of Water Evaporated per Kilogram of Coal.	Product of Evaporation for the quantity of Coal burnt per hour and per Square Metre of Grate Surface.	Depression in the Smoke-box in Centimetres of Water.	Pressure in the Boiler in Atmospheres.	Observations.
I.	kgs. 4·5	1,100	6	6	Non-bituminous.
II.	5·5	1,250	6	6	
III.	6·3	1,500	12	8	
IV.	7·0	1,600	12	8	Semi-bituminous.
V.	7·5	1,700	12	8	

BITUMINOUS COAL, SUITABLE FOR MAKING COKE.

Type I. A mixture of at least 50 per cent. of quartz-sand and 50 per cent. of finely-pulverized coal should give an agglutinated coke.

Type II. A mixture of at least 60 per cent. of quartz-sand and of 40 per cent. of pulverized coal should give an agglutinated coke.

The bituminous coals ought to yield a minimum of 18 per cent. of volatile matters, and their yield of ashes should not exceed 15 per cent. These coals should not be burnt alone in the fire-box of the locomotive; they are not submitted to evaporation experiments. In order to ascertain whether the fuel delivered really corresponds with the description, the following trials are made :—

Evaporation Experiments.—The bituminous and semi-bituminous coals are tested in two locomotive-boilers specially arranged to readily determine the quantity of water evaporated, the weight of coal consumed per hour and per square metre of grate-surface, and the quantity of ashes left after combustion in the smoke-box and ash-pit. The steam produced is in part carried away in the chimney to create an artificial draught; the excess escaping

freely. The intensity of this draught is regulated at will, and is measured by a water manometer in direct communication with the smoke-box. A metallic gauge gives the pressure of steam, and two injectors feed each boiler from water contained in a graduated reservoir, and special for each boiler. The fire is lighted with a quantity of coal, which is not taken into measurement in the trial. When the boiler is under pressure, the experiment is commenced by noting first the hour and the level of the water in the reservoir and in the boiler. The fire is maintained as regular as possible, and in such a manner that the draught may be indicated by a depression of the gauge, which differs according to the nature of the combustible. The last shovelful of trial coal being cast on the fire, the experiment is concluded when the pressure has fallen to $\frac{1}{2}$ atmosphere. The level of the water in the boiler is then restored to its initial height. The difference of level of the water in the reservoir, ascertained before and after the trial, and the weight of fuel used, give the quantity of water evaporated per kilogram of coal. The coal burnt, the grate surface, and the duration of the experiment, determine the weight of coal burnt per hour and per square metre of grate surface. The average depression in the smoke-box, as well as the average pressure of steam, are known from the notes taken during the course of the trial. It only remains to weigh the ashes in the smoke-box, those of the ash-pan and the clinker, to be informed of the evaporative power of the coal and the manner in which it supports the draught.

Laboratory Experiments.—All the coals are tested to ascertain the quantity of water that they contain, their yield of ashes, of solid carbon, and of volatile matters. The bituminous coals likewise undergo a trial with the object of ascertaining their caking power. An intimate mixture of the coal, finely pulverized, and sand, reduced to an impalpable powder, is heated in a porcelain crucible to a bright red heat until the volatile matters have completely disappeared in a reducing atmosphere. It is thus found what is the quantity of sand that must be added to the coal, so that the mixture may give, after complete evaporation of the volatile matters, a resisting mass, which, under the pressure of the fingers, only breaks into pieces without crumbling into dust.

The Paper is accompanied by a printed list of instructions issued by the Minister of Public Works on the 3rd of June, 1882; and by two tracings, from which the Figs. in the text have been prepared.

(Paper No. 2280.)

“A Simple Method of Ascertaining the Discharge of Rivers.”

By Prof. A. R. HARLACHER and H. RICHTER.

(Abstract.)

IN order to ascertain the discharge of a river by this method, a cross-section of it must be surveyed, and the velocity of the current in the same be measured. The velocity may be accurately observed by a current-meter, and for an exact calculation of the discharge must be measured in a sufficient number of vertical lines distributed all over the cross-section, and in several points of each line from the surface to the bottom. In rivers of moderate velocity and depth, such observations can be made with comparative facility and promptness; but in more rapid rivers, and of greater depth, they require much time and great pains. This, of course, also holds good in ascertaining the discharge of rivers of moderate size at the time of flood, when the observations are, however, unfavourably influenced by the water-level being commonly subject to frequent changes, for which reason the measurements should then be hurried as much as possible.

In case of the want of requisite measuring-appliances, it is expedient to measure the surface-velocity only; and then, of course, the discharge can only be calculated by means of certain proportional numbers. The discharge might be ascertained, in a very simple way, if an empirical formula could be found for the relation between the mean velocity U in the cross-section, and the greatest surface-velocity V , or the mean surface-velocity v_m , which, however, has been proved to be impossible; the proportion $\frac{U}{V}$, as well as $\frac{U}{v_m}$, appeared, on the contrary, to be subject to considerable changes, occasioned by the shape of the cross-section, as well as by irregularities of the river-bed, and also slightly by the roughness of the bottom.

It is impossible to form a direct estimate of the mean velocity at a cross-section by the observed surface-velocities; but there is a possibility of calculating the discharge, by finding a certain

relation between the mean velocity v_m in the verticals of a cross-section and the surface-velocity v_s . For this purpose the Authors have calculated the proportion $p = \frac{v_m}{v_s}$ for about three hundred vertical curves of velocity in twenty-eight measurements of discharge in Bohemian rivers, and in the Danube at Vienna. In all these measurements Harlacher's current-meter was used.¹ The mean surface-velocity v_s in a certain cross-section was obtained by taking the measured v_s in the relative points of the level of the water as ordinates, and by laying from shore to shore a continuous curve through the points thus obtained, and dividing the area enclosed by this curve and the level of the water by the width of the latter. In the same manner the mean of all the v_m could be obtained.

From a calculation of all the v_m and v_s for each of the twenty-eight measurements, the following values of the proportion p were obtained:—0·79 once, 0·82 twice, 0·83 six times, 0·84 six times, 0·85 five times, 0·86 once, 0·87 twice, 0·88 three times, 0·89 once, and 0·91 once.

Supposing the cross-section to have been taken, and the velocities to have been measured; on calculating the discharge, by the application of the mean value of p , a quantity will be obtained varying, but very slightly, from the discharge computed from all the velocities measured in the verticals of the section in question. In the different cross-sections of the rivers where these surveys were made, the highest velocity varied from 0·60 metre to 3·00 metres per second, the greatest depth from 0·80 metre to 8·00 metres, and the greatest width from 50 to 420 metres; the smaller velocities, however, were measured only in the sections of moderate depth. The nature of the bottom was very variable; for the most part the greatest value of p occurred with a sandy bottom, whereas the smaller values were found with gravel bottoms, the gravel being of the size of the fist in bottoms of the roughest nature. The proportion p in rivers not varying much in size, velocity, depth and nature of bottom, from the above-mentioned limits, may be taken at 0·85.

An almost identical result has been obtained from measurements of velocity in other places. Thus, in two hundred vertical curves of velocity surveyed by Swiss engineers, the mean value of p was found to be 0·835. In the measurements taken a few years ago in Holland, in the Rhine and its branches, the value of p was ascertained to be 0·87, and the probable error of that value,

¹ Minutes of Proceedings Inst. C.E. vol. lxvii. p. 358.

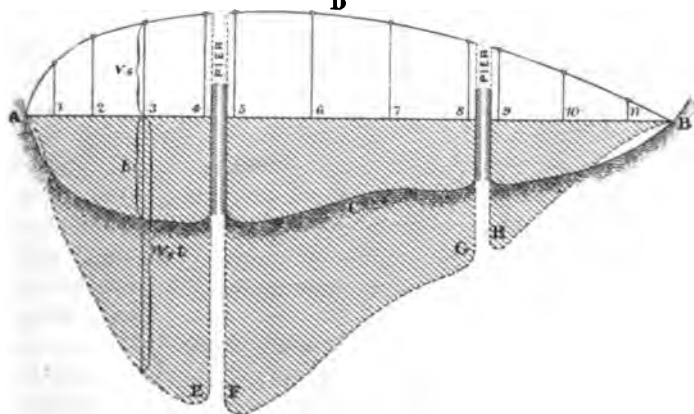
ascertained by the application of the method of least squares, was proved to be insignificant.

The Authors have used bridges, from which the surface-velocity was measured by an electric current-meter let down on a small line. One great advantage in this mode of measurement is that neither boats nor any other appliances are wanted. Of course, only bridges with wide spans, those with iron superstructures, are suitable, and a proper position of the piers, lest the motion of the water in their vicinity may be affected by eddies.

The velocities having been measured all along the reach of the river at a sufficient number of points, 1, 2, 3 . . . of the section A C B, Fig. 1, between the piers of a bridge, the curve of the

FIG. 1.

D



surface-velocities A D B may be drawn. By calculating for the single points 1, 2, 3 . . . , and for a sufficient number of intermediate points, to be chosen in accordance with the formation of the bottom, the product of the surface-velocity v , by the corresponding depth t , and by plotting the values v, t as ordinates, the points are obtained by which the curves A E, F G, and H B bordering the hatched surfaces, are determined. The content of these surfaces multiplied by the proportion $p = 0.85$ gives the volume of water passed through the section. The Authors have taken successfully more than seventy measurements by the above method in Bohemian rivers, many of them being in the Elbe and the Moldau.

The Paper is illustrated by several diagrams, from which the Fig. in the text has been prepared.

(Paper No. 2281.)

“Prediction of the Height of the Elbe in Bohemia and Saxony.”

By Professor A. R. HARLACHER and H. RICHTER.

(Abstract.)

THE Bohemian Elbe is navigable for large cargo-boats below its junction with the Moldau at Melnik; but the main traffic commences at Aussig, where enormous quantities of lignite are shipped; and at Tetschen, near the Saxon frontier, goods, such as cereals and sugar, intended for conveyance to England by way of Hamburg, are first transferred from railway trucks coming from the interior of Austria. It is often of great importance at these freighting-centres to be able to predict the probable height of water. In the case of floods, to do this even one day in advance, it is necessary to take into consideration the heights of the Moldau at Prague, the Little Elbe at Brandeis, and the Eger at Laun. Of late years the readings of the river-gauges at these three places have been telegraphed daily to the above-mentioned freighting-centres; but the observations have not been sufficiently long-continued or extensive to predict with accuracy the height of the Bohemian Elbe from the heights of the tributaries only. The solution of the problem is relatively easy if the discharges of the rivers are known. The latter point was accomplished, in respect to their hydrometric section, by the Hydrographic Commission of the Kingdom of Bohemia, under the direction of Professor Harlacher. As almost all the Bohemian rivers fall into the Elbe, measurements of that river were carried out at Tetschen to ascertain the discharge, the series being brought to a close in 1881. For this purpose the velocities, at mean and at low-water level, were measured by a current-meter, at several points between the surface and the bottom, on a sufficient number of vertical lines; at high-water the velocities were measured, at the surface only, by floats, and the discharge was calculated on the supposition that in each vertical the proportion between the mean velocity and the surface velocity was 0.85. The discharge of the Moldau is on an average much larger than that of the Little Elbe. The discharges of these rivers at different levels were ascertained respectively at Prague and at Brandeis, or in favourable sites below this place. The measurements, which were undertaken after those at Tetschen, had been

finished, have now been brought to a close. Numerous measurements have also been taken of the Eger at Laun. All the measurements were made by an electrical current-meter, in most cases from bridges.

The discharges, in cubic metres per second, of the rivers under consideration, are given in the following Table :—

Height in Metres of Water on the Gauge.	Discharge in Cubic Metres per Second.			
	Moldau at Prague.	Little Elbe at Brandeis.	Eger at Laun.	Elbe at Tetschen.
-0.50	27	..	8	73
0.00	59	51	19	161
+0.50	136	93	45	282
+1.00	285	137	73	435
+1.50	479	200	103	621
+2.00	721	287	140	839
+2.50	966	402	188	1,054
+3.00	1,345	..	284	1,269
+3.50	1,800	..	407	1,498
+4.00	2,260	..	..	1,742
+4.50	..	..	..	1,998
+5.00	..	..	..	2,268
+5.50	..	..	..	2,549
+6.00	..	..	..	2,843

When the water-level of the Moldau, the Little Elbe, and the Eger was stationary, their combined discharge, augmented by the drainage from the territory below the points of measurement of these rivers down to Tetschen, estimated at 10 per cent. of the total discharge, should be equal to the discharge of the Elbe at that place. Thus, knowing the readings of the river-gauges at Prague, Brandeis, and Laun, the height of the Elbe at Tetschen might be predicted. This general proposition bore the test of experience, but it was necessary to modify it somewhat in time of floods, according to the form of flood-waves moving down the tributaries, each of which might be very differently affected, so that under these circumstances the prediction of the maximum height of water at Tetschen, especially in a rapid rise, was very difficult. The Authors give a series of diagrams, which show a close correspondence between the height of the River Elbe at Tetschen predicted one day in advance, and the actual height as observed. At present the Authors confine themselves chiefly to announcing telegraphically from Prague, during the shipping season, the probable height of the greater floods, one day in advance for Aussig and Tetschen, and one day and a half for Dresden.

*(Students' Paper No. 224.)***"Hydraulic Appliances at the Forth Bridge Works." ¹**

By ERNEST WILLIAM MOIR, Stud. Inst. C.E.

THE Forth Bridge, in its manufacture and erection, is a work well adapted to the use of hydraulic and other special machinery, and no opportunity has been lost by Mr. W. Arrol in the introduction of labour-saving plant. There are two forms of accumulators in use at the works, through which the high-pressure water is pumped, one form having a 16-inch cylinder loaded by dead weight, the other having an 8-inch cylinder weighted by steam. The larger one is that used for general work, the smaller, which is portable, only for isolated jobs, or in case of a break down. All the compression members of the cantilevers are tubular; the bottom members and the columns forming the main steel pier are circular in section, the struts being flattened, so as to simplify the junctions and intersections with the other parts of the triangulation.

The heaviest plates, weighing 34 cwt., are in the bottom members of the cantilevers, their dimensions being 16 feet by 4 feet 9 inches, and they are bent in the arc of a circle with a radius of 6 feet. A hydraulic press (Plate 9, Figs. 1 and 2) was made for the work, capable of putting a load of 800 tons between the cross blocks, with a pressure of 1000 lbs. per square inch on the cylinders. It has four rams 24 inches in diameter, connected at the top by a heavy cast-iron cross-head, upon which is placed the lower or concave "cross" block. Eight steel standards, 7 inches in diameter, are secured to the cylinder castings, and support the upper table, as well as form guides for the lower block while it is being raised.

The rams are packed with tallowed white rope in ordinary glands, this form of packing being very much more economical in such large diameters than any form of cup leather.

The water is controlled by two ordinary brass conical screw-down

¹ This Paper was read at a meeting of the Students on the 1st of April, 1887, and was awarded a Miller Prize in the Session 1886-87.

valves, one for admission and one for release, the exhaust water being forced out by the weight of the rams and lower table. The plates to be set are drawn from an adjacent gas-furnace, at a red heat, upon the lower cross block of the press, by means of a chain working over multiplying pulleys on a vertical hydraulic ram, and when in position are squeezed between the dies to the desired form. The plates are removed, while warm, from the press, and laid aside to cool, during which process they generally become distorted, requiring to be adjusted when cold, by placing them in the press a second time. The hydraulic cranes used throughout the sheds for handling the material, of which Plate 9, Fig. 3, is a sectional elevation, are simple in design and efficient in working. The cast-iron cylinder is let into a cast-iron box filled with concrete, forming the foundation, and is bored to $4\frac{1}{2}$ inches for the steel ram. The cantilever jib is rigidly attached to the head of the ram, and is lifted or lowered with it, transmitting the shear of its own weight and load, direct to the water in the cylinder; the bending moment being taken up by two pairs of pulleys running within the channels forming the mast. The distance between the centres of these wheels is 6 feet, being made as small as is consistent with strength to allow of as great a lift of the jib as possible. The cast-iron distance-pieces between the channels of the mast form bearings on which the crane revolves, the lower one being split embraces the cylinder just above its foundation, while the upper one works in a bearing, attached by means of a plate and long angle-stays to the roof-trusses of the sheds. The loads are slung to a small carriage, which is travelled by means of a system of chain wheels on the horizontal bottom member of the cantilever jib. A common three-way cock controls the admission and release of the water, the weight of the jib and ram serving to force out the exhaust, when the cock is turned in such a position to allow of this being done. The thickness and the number of courses of plates in some portions of the bridge is so large, and the necessity for machine-riveting therefore so great, that special plant had to be made for the work. Plate 9, Figs. 4 and 5, represent the machine used for riveting the upper and lower bed-plates, which rest upon the tops of the granite piers supporting each cantilever. The bed-plate is supported on columns about 4 feet 6 inches above its final level.

The machine is composed of two box-girders bound together at their ends by bolts and plates, and faced on their inner sur^f. Each girder is provided with a cast-steel slide, having a recess at right-angles to its longitudinal axis. The ba

12-inch cylinder is contained within the slide, and can be moved transversely, or longitudinally by suitable screw-gearing.

The whole machine travels on wheels at its ends, which rest upon timber runners having "flats" spiked to their upper surfaces.

Both the cylinders are controlled by one cock, to which six pipes are attached; two of these are for the main pressure and exhaust, and two for each cylinder. Only one of the two entering each cylinder is controlled by the valve, that which enters it nearest the base; to the other the high-pressure water has constant access. The use of these two connections will be better understood by referring to Plate 9, Fig. 6, which is a section of a 15-inch hydraulic ram, used in the works for the setting of heavy plates and connected in the same way as the riveting cylinders. S, the cylinder, has two connections coming from the cock Q, one, B, on the under side of the piston, and one, C, on the upper side of the same. The lower one only can be controlled by the cock, the water being always free to enter the upper one. There are two cup leathers L, the upper one, which is always in action, faces downwards, and L', which faces upwards, only comes into use when the water is allowed to escape from the under side of the ram R; for in that case the pressure is no longer equal on both sides of the leather, expanding it, at the same time the pressure in the annular space in the front of the piston forces in the ram. On again admitting the water to the under side of the ram, the pressure becomes equal on both sides of the lower cup leather, and the lifting area of the jack is that due to the smaller diameter.

With the above riveter eleven hundred rivets, $1\frac{1}{8}$ inch in diameter, and from $5\frac{1}{2}$ to 6 inches long, have been put in in one day of ten and one-quarter hours. In the complex junctions of the tubes, where it is impossible to work one of the ordinary riveting-machines, but where it is a matter of importance to secure the advantages of hydraulic over hand-riveted work, it was necessary to devise something entirely new. Whatever mechanism was employed would require to be of such dimensions that it would pass through a manhole 16 inches by 13 inches, and of such a weight as to be easily handled by one man. Mr. Arrol decided to adopt a high pressure with a correspondingly smaller piston area, and it was found that with a pressure of 3 tons per square inch, a riveting cylinder 4 inches in diameter was sufficiently powerful to do the work; the weight of such a cylinder and fittings does not amount to more than 40 lbs., and its overall dimensions are only 10 inches by 6 inches.

Plate 9, Fig. 7, is a section of one of two skewbacks or main junctions over the caisson piers, showing the position in which these cylinders were employed. The two cylinders are connected by small copper piping sufficiently flexible to bend easily, and provided with suitable hinged joints to one tee piece, from the third arm of which is led a copper pipe of larger diameter to the pressure multiplier, which is large enough to keep two or three pairs of cylinders in operation. Plate 9, Figs. 8, is a section of this machine, C is a brass casing or cylinder, having two diameters, the squares of which are in inverse ratio to the pressure on the two ends of the ram.

The plunger has a piston upon its end of the diameter of the lower part of the cylinder.

Referring to the diagram of the connections, Fig. 8, F is the flexible hose bringing water at 1,000 lbs. per square inch to the under side of the conical valve V, as well as leading through the branch B to the cock Q, which is an ordinary plug cock, communicating through the pipe P with the base of that part of the cylinder having the larger diameter. From the space on the upper side of the conical valve V, there are two branches, one leading into the end of the cylinder having the smaller diameter, the other controlled by the screw-down valve S, to the small riveting-rams. The cock Q being turned to exhaust, and the pressure at 1,000 lbs. filling (after lifting the conical valve V) the smaller cylinder, the water below the larger piston is forced out, and the ram brought to the commencement of its stroke. When a rivet is to be struck the screw-down valve S is opened, filling the piping and small rams with water, at 1,000 lbs. per square inch. The rivet is squeezed as far as the pressure of 1,000 lbs., on an area of 12 square inches, will squeeze it, when it is necessary to put on the higher pressure of 3 tons. This is done by turning the cock Q, which allows the water at 1,000 lbs. pressure to enter the larger cylinder, thereby increasing the pressure in C'; thus shutting the conical valve against the water at the lower pressure and preventing it from leaking back into the mains, while at the same time the rivet gets the necessary load to properly compress it. For riveting the vertical and diagonal tubes, machines of special design are employed, similar in principle to the one already described in connection with the bed-plates, but differing from it to suit the form and position of the tubes on which they work.

Plate 9, Fig. 10, is a vertical section of one of the 12-foot tubes, showing this machine in place, Fig. 9 being a sectional plan. R and R' are two heavy steel girders, 22 feet apart, kept at their

correct distance by angle-iron framing, which when covered with small mesh netting makes a complete cage, from which nothing can fall. The rings are kept at a uniform distance from the skin of the tube by hard wood wedges driven in opposite the stiffening H beams. G is the vertical riveting girder held by cast-steel clips to the outer flange of the circular rings, but it can be moved to any position in their circumference by the small hydraulic jacks C, Fig. 9. On the face of the girder, held in a cast-steel sliding saddle, is the riveting cylinder, to which there is also attached a small platform for holding the men, whose business it is to attend to the closing of the points of the rivets. The saddle, with its stage and cylinder, can be raised or lowered to any position by the small hydraulic jack B, the cock controlling which is within easy reach of the men on the stage.

Holes are provided in the faces of the girders as well as round the circumferences of the rings, against pins passed through which the rams are made to bear, either to raise the cylinder or to alter the radial position of the girder. There is then on the outside of the tube a vertical girder, movable to any position round the circumference, carrying a cylinder which is capable of putting a pressure of 40 tons on the point of a rivet on any part of a length of 17 feet. The inside girder does not travel bodily, but is made to rotate by suitable gearing, within easy reach of the men on the small lifting platform, upon trunnions at its ends (Plate 9, Fig. 10). These trunnions are held in a central position by angle-frames at the upper and lower ends of the girder, which are wedged to the faces of the longitudinal stiffening beams of the tube, and rest upon small movable brackets.

The cylinder is in this case far from its work, but is provided with a long snap, having a movable cranked end, so made to get in at the backs of the angles on the H beams (Fig. 9). The cylinder, platform, and men are raised and lowered by a small hydraulic jack, in the same way as on the outer riveting girder. There is then inside a cylinder of the same power as that without, which can be brought to bear on the head of any rivet in a length of 17 feet of the tube. The whole machine is suspended to the platform above, and is raised with it in 16-foot stages, or sufficient to put on one course of plates.

The water is admitted to both cylinders at once from one cock, but is delayed by a suitable valve from entering the outer cylinder until the rivet is well pushed into the hole from within.

The rivets are heated in a specially designed oil-furnace, just above the machine, inside the tube, and have been put in at the

rate of eight hundred per day of ten hours. The machines used in the diagonal tubes are similar as far as the outer rings are concerned, except that instead of being circular they follow the outline of the flattened tubes upon which they work. The longitudinal girder is made to traverse a path at a uniform distance from the inner sides of the plates, upon raised ridges, which are attached to the upper and the lower diaphragms, forming the inner framing of the machine.

The last subject to be dealt with in this Paper is the raising by hydraulic jacks of the approach viaducts, the larger of which is 1,680 feet long, and weighs about 2,000 tons. The viaducts are in 168-foot spans, continuous over every second pier, and so closely connected at the non-continuous pier that it was decided to lift all the girders at one time. Two inverted 15-inch jacks were employed on each pier; these were fixed into a temporary cross-girder bolted to the under side of the viaduct. Four stacks of hard wood blocks were placed beneath the cross-girder, which, during the time the lifting operations were going on, were kept closely packed by means of long slip wedges. There was also placed under each cylinder a pile of blocks, against which the rams pressed while the girders were being raised. On the completion of a lift, which was always enough to allow of the building of three courses of the pier, the stacks were removed one by one, to enable the masonry to be set beneath them, being again replaced after the new work had been allowed sufficient time to set. When the three courses of the pier were finished, forty-eight hours were allowed for the proper setting of the cement, before another lift was taken. The high-pressure water was supplied at 34 cwt. per square inch, by steam-pumps, the engines of which, during the building operations, were used to work by rope-gearing the friction-hoists for setting the masonry. The rate of building and lifting, including the time allowed for the setting of the cement, was about 10 feet per month, and a lift of between 4 and 5 feet occupied about two hours. The north and south viaducts have been raised, by the means here outlined, over 100 feet without any mishap, and are now at their final level.

This communication is accompanied by several drawings, from which Plate 9 has been engraved.

OBITUARY.

EDWIN ARTHUR BERNAYS was the second son of Adolphus Bernays, Ph. Dr., Professor of German at King's College, London. He was born in London in 1822, and was educated at St. Paul's School and at King's College. In 1841 he received an appointment at Her Majesty's dockyard, Woolwich, in the Department of the Director of Works. Woolwich was at that time one of the great Government shipbuilding yards, and young Bernays, by his untiring energy and application to his duties, soon acquired the confidence and esteem of his chiefs. At that time civil servants of his grade were termed "Clerks of the works," and the position marked out by that title was felt to be hardly a sufficient recognition of the services rendered by a body of men who were frequently charged with the active superintendence of public works of an important character. With the approbation of his chiefs, Mr. Bernays became the leader and spokesman of his colleagues in laying the claims of the Clerks of the works before the Government. The question involved was more than that of a mere name, and the authorities recognised its importance by creating the grade of "Civil Engineers" in the Works Department of the Admiralty.

In 1859 Mr. Bernays was appointed to the rank of Assistant-Civil Engineer. Whilst at Woolwich he superintended the construction of many important buildings, including the Rigging House, the Saw-Mills, the Iron roofing of large span over the ship-building slips, the hydraulic coal store, &c. He also suggested and superintended the laying down of cast-iron tram-plates throughout the dockyard, an improvement which greatly facilitated the transport of heavy articles by ordinary wheeled vehicles; and the improved stores, which were erected for drying planks, were, in a great measure, of his special contrivance. In 1860 Mr. Bernays was appointed to Pembroke dockyard, where he superintended the enlargement of the dry dock, and several other works of magnitude. In 1862 the enlargement of Chatham Dockyard, then recently commenced, required the superintendence of a man of energy and experience. Mr. Bernays was selected for the post, and he here found fitting and congenial employment for the remainder of his active life. This great work, the major portion

of which was designed by Sir Andrew Clarke, R.E., G.C.M.G., was carried to completion entirely under the care of Mr. Bernays, whose first appointment thereon was as Assistant Civil Engineer under Major-Gen. Charles Pasley, R.E., at that time the Superintending Engineer. Subsequently, upon the appointment of General Pasley in 1873 to the post of Director of Works of the Navy, Mr. Bernays was appointed as Superintending Civil Engineer to the sole charge of the Works at all the Admiralty establishments at Chatham and Sheerness. The extension works at Chatham may be briefly described as the transformation of St. Mary's Island, then a dismal swamp, intersected by muddy tidal creeks, into an enormous dock-yard, replete with all the appliances of modern science for the building and equipment of war-vessels of the largest size. These works comprised, amongst other features, a "repairing-basin," having a mean length of 1,270 feet, a width of 700 feet, and an area of 20 acres 16 perches; a "factory-basin," of a mean length of 1,245 feet, width 700 feet, area 19 acres 3 roods 36 perches; a "fitting-out basin," somewhat irregular in form, having an area of 27 acres 3 roods; a tidal dock for the discharge of steam-colliers; extensive machinery-shops and engine-houses; a deep artesian well, &c. The total cost of the works has been estimated at over £2,000,000 sterling.

It is to be regretted that Mr. Bernays did not live to present to this Institution a Paper upon the construction of these remarkable works, but students will find ample details thereon, together with much other information, in the Lectures which he delivered at the School of Military Engineering at Chatham, at the request of the Commandant.¹ A few words from one of his Lectures may illustrate the spirit in which he performed his labours. He says: "I cannot tell you how interesting an occupation it has been to me to watch the growth of this great engineering work, and see a large tract of amphibious ground, half land, half water, gradually pass from a state of chaotic desolation into the vast establishment of which any nation may be proud."

A large number of convicts were from time to time employed on the works, and Mr. Bernays took a keen interest in the utilization of their labour for the service of the State, employing them not only on the rougher kinds of manual labour, but frequently on

¹ "Lectures. Chatham Dockyard Extension Works. Delivered at the School of Military Engineering, Chatham, Autumn Session, 1872. By E. A. Bernays, Esq., C.E." Folio. Old Brompton, 1872. Ditto, ditto, Session 1879. Folio. Chatham, 1879.

more skilled descriptions of handicraft. In the Lectures above referred to he has recorded, in some extremely practical remarks, his opinion on the subject of the employment of convict labour in general.

If a good workman be known by his tools, an able engineer may be recognized by the quality of the materials which he uses, and their special applicability to the particular works under his charge. It was a favourite remark of Mr. Bernays that the Government was a sure paymaster, and that he saw no reason why it should not get full value for its money. The specifications which he drew up for the supply of materials, exhibit great practical sagacity ; they are simple in their working, avoiding all fanciful and vexatious conditions, but conveying to the contractor, in terms which are mainly those in use in his particular trade, the most explicit instructions as to the requirements of the engineer. To his extreme care in the selection of materials may in part be attributed the great success of the new departure which he inaugurated in the employment of Portland cement concrete. This material was not originally specified in the plans for the Chatham extension works, but at the recommendation of Mr. Bernays its use was introduced on a very extensive scale, for purposes and by methods which were in many respects without precedent. The results proved to be entirely satisfactory, and a great saving was thereby effected in the cost of the works ; one especial novelty consisting in the construction of important sections of the work with concrete of an entirely satisfactory nature, composed of 12 parts of gravel to 1 part of Portland cement ; another, in the ingenious method which he adopted for coating this rougher concrete with a facing of a finer description, where smoothness of surface was required, the two layers being worked together so as to become thoroughly incorporated at the line of junction.

In May, 1880,¹ a Paper by Mr. Bernays on "Portland Cement Concrete," was read before the Institution, for which the Council awarded a Telford Medal and Premium. It has proved to be a valuable treatise on a most important engineering material, no methods being there proposed which had not first been tested by careful and laborious experiment, and afterwards put to the severer proof of successful employment upon works of great magnitude.

In 1882, upon attaining the age of sixty, Mr. Bernays, in the ordinary course, would have been superannuated, but the Admiralty

¹ Minutes of Proceedings Inst. C.E. vol. lxxii. p. 87.

decided to retain his services for a further period of two years, which period was subsequently extended until 1886, the Lords of the Admiralty stating that their decision was arrived at "in consideration of the important duties performed by Mr. Bernays, and in view of his further retention being desirable, solely with reference to the interests of the public service." He had the gratification of superintending the successful completion of those great works upon which he had so long laboured, and which were opened on the 3rd October, 1885, and in September 1886 he retired from the public service. The following extract from a letter, addressed to Mr. Bernays by the Lords of the Admiralty on the 2nd of October, 1886, will serve to show the estimation in which he was held by his official superiors: ". . . they desire to convey to you their sense of the very valuable, zealous and efficient services rendered by you during your long service of more than forty-five years, especially in the supervision of the work for the extension of the (Chatham) Dockyard; the satisfactory completion of which is to a great extent due to your care and ability."

Mr. Bernays was an indefatigable worker, not only in the discharge of his professional duties, but also in philanthropic enterprises of various kinds, especially in connection with the education of the poor, and in active co-operation in parochial work of the Church of England. A faithful and upright servant of the State; an affectionate husband and father, constant and true-hearted in his friendships, his loss is deeply lamented by many who had hoped that he would have enjoyed, for many years to come, the leisure which he had so amply earned.

Mr. Bernays was elected a Member on the 1st of April, 1879. He died at Worthing, on the 27th day of September, 1887.

CHARLES GRAHAM BLATCHLEY, the eldest son of the late Charles Blatchley, Commander R.N., born at Ringwood, near Bristol, on the 23rd October, 1828. About the year 1845, Mr. Blatchley became a pupil to the late Mr. William Glennie, who was then stationed at Dawlish, as Resident-Engineer for the South Devon Railway. After completing his pupilage he removed to Ipplepen, being employed as Resident Engineer on the South Devon Railway, between Newton-Abbot and Totness. On this work being finished, Mr. Brunel sent him to the Mickleton Tunnel on the Oxford, Worcester, and Wolverhampton Railway, a piece of work which had given considerable trouble to con-

tractors, but which the Company successfully completed under Mr. Blatchley's superintendence. During its progress he resided at Chipping Campden. From thence, in the year 1852, he removed to Saltash, becoming Resident Engineer for the portion of the Cornwall Railway lying between Devonport and St. Germans, his work including the setting out of the Royal Albert Bridge. In 1860 he removed to Falmouth, having been appointed Resident Engineer for the branch of the Cornwall Railway between Truro and that town, under Mr. R. P. Brereton, M. Inst. C.E., as Chief Engineer.

After the Falmouth line was opened, Mr. Blatchley went to Dublin in charge of the Dublin Trunk Connecting Railway, and on the stoppage of that undertaking he acted as Resident Engineer for his friend Mr. W. B. Lewis, M. Inst. C.E., on the Worcester, Bromyard, and Leominster Railway, residing for some three years at Bromyard, Herefordshire. On the completion of the line to that place, in 1878, he retired to Cheltenham for the education of his daughters, only occasionally being employed in professional matters. During his residence in Cheltenham he was busily occupied in many religious and philanthropic efforts, and there, to the sorrow of a large circle of attached friends, he died on the 2nd October, 1887, aged fifty-eight years.

Mr. Blatchley was a man of singularly consistent character; he sought to do everything thoroughly and well, and this in the whole of life, as well as in particular duties, and the conscientious care with which he carried out the details of every engineering work committed to his charge, appeared also in family and social relations, and in the performance of the many public services he voluntarily undertook. Although of quiet and retiring habits, his usefulness caused him to be widely known and greatly esteemed wherever he resided, and he was followed to his grave in Leckhampton churchyard by many of the leading residents of Cheltenham. He was elected a Member on the 1st of December, 1868.

WILLIAM BARBER BUDDICOM, who died on the 4th of August 1887, at the age of seventy-one years, was one of the enterprising, clear-headed, and courageous engineers of the early railway days; men of the stuff of which George Stephenson was made, and who seemed created especially to meet the demand which everywhere arose for persons competent to direct and control the development of the new means of communication. His career was of exceptional interest as showing how greatly the mechanical

resources of various nations on the Continent have been developed by such Englishmen as Cockerill in Belgium, Buddicom in France, Guppy in Italy, and others whose work has been recorded from time to time in these volumes. He was the son of the Rev. R. P. Buddicom, Perpetual Curate of Everton, near Liverpool, in which village he was born on the 1st of July 1816. He was educated at home, and at the age of fifteen was apprenticed to Messrs. Mather, Dixon & Co., ironfounders and engineers of Liverpool. On the completion of his apprenticeship he was appointed a Resident Engineer on the Liverpool and Manchester Railway, for the section between Liverpool and Newton Bridge, having for his engineering chief Mr. Edward Woods, Past-President Inst. C.E., and as his superior officer for other duties, Mr. Henry Booth, who, though nominally only the secretary, was virtually the manager of the railway. Mr. Buddicom's work was very varied, including, as it did, the maintenance of the permanent way, bridges, tunnels, stations, &c., the substitution of 75-lb. rails for those of 35 lbs. first laid, and the re-ballasting of the road. The police of the line and stations, and the care of the ropes and engines working the Wapping and Lime Street tunnels, also formed part of his duties, while he had to prepare the pay-sheets of the workmen engaged in these departments, and also to distribute the money. His engagement was for two years, at the end of which time the directors made him proposals to remain at an increased and increasing remuneration; but with a foresight remarkable in one so young, he declined to bind himself for a number of years, doubtless feeling that opportunities would arise for rapid advancement. In this he was fully justified, for while negotiating with Mr. John Cockerill for an appointment at his well-known works at Seraing, near Liège, an offer came from Mr. Locke of the post of Resident Engineer for the construction of the Glasgow and Paisley joint line. This Mr. Buddicom accepted, and here he remained till 1840, when, again on the recommendation of Mr. Locke, he was appointed Locomotive Superintendent of the Grand Junction Railway. He thus, at the age of twenty-four, acquired a post of great importance and responsibility, for in those days of heavy fuel-consumption, even more than now, the locomotive department was the chief factor in the expenditure of a railway. Mr. Buddicom succeeded in reducing considerably the working-expenses, and he originated the system, since become universal, of giving to drivers and firemen premiums for economy in the use of fuel and oil, and, later on, for increased care of their engines. The results were so satisfactory that they were specially referred to in the

Directors' report to the meeting of February 1841, in a way most gratifying to a young officer. At this time the engines mostly in use were of the Bury type, and the frequent failures of the crank-axles was a considerable source of expense and anxiety. The number of engines was limited, and several different sizes existing, the exchange of pieces possible between different engines was practically inappreciable. It was, moreover, becoming generally recognized by engineers that the locomotive was only in its infancy, and that serious modifications would be needed in order to make it equal to the daily increasing requirements of the railway system. In Mr. Buddicom's frequent interviews with Mr. Locke these troubles were much discussed. Locke was in favour of straight axles, outside cylinders, large driving-wheels, and bigger boilers. In those days the idea strongly obtained that high centre of gravity was necessarily incompatible with steadiness of running. After many projects had been mooted and fully discussed, one, the joint idea of Mr. Buddicom and the then foreman of the repairing-shop, Mr. Alexander Allan (afterwards so well known in connection with his valve-motion), was submitted to Mr. Locke, who obtained from the Directors authority to have an engine built. The order was given to Messrs. Sharp, Roberts & Co., of Manchester, but Mr. Richard Roberts, declared the system radically bad. In consequence, the engine was built at the Company's own works, and was the first of a type used for many years by Mr. Buddicom and his successors, Mr. F. Trevithick, Mr. Ramsbottom, and Mr. Webb. Of course improvements were made as more powerful and faster engines were required, but the principle of the engine and its main features of construction remained the same. Early in 1841 it was decided to transfer the Grand Junction Company's repairing-shops from Edge Hill to Crewe, then a small roadside station. Mr. Buddicom was charged to prepare the plans, the estimate amounting to between £71,000 and £72,000, which was then considered a large outlay for such a purpose. These plans were carried out, and the buildings still exist as portions of the great establishment at Crewe, now increased to meet the mechanical wants of the whole London and North-Western system. At the commencement of these works, Mr. Locke, who had been named by a body of English capitalists, engineer of the Paris and Rouen railway, finding it difficult to procure the rolling-stock and fixed plant in France on reasonable conditions, suggested that Messrs. Brassey and Mackenzie, the contractors for the railway, should, in conjunction with Mr. William Allcard of Warrington, then con-

tractor for permanent way on the Grand Junction Railway, and Mr. Buddicom, jointly contract to supply the necessary plant. The conditions were that the manufacturing establishment should be built in France, so as to be useful to the railway company, if, at the completion of the contract, the latter wished to acquire them. The idea took concrete shape as the firm of Allcard, Buddicom & Co., and their proposals being accepted, some temporary buildings, previously used for the manufacture of stationary engines, were leased at Chartreux, near Rouen. Preliminaries being thus avoided in the erection of the buildings, Mr. Locke, to still further economise time, adopted, as the type of engine to be constructed, the design for the Grand Junction locomotive before-mentioned. Having arranged with his partners to take charge of the works in all matters relating to mechanical operations, Mr. Buddicom resigned his position as Locomotive Superintendent of the Grand Junction Railway in July 1841. Great exertions were necessary to execute the work contracted for within the limited time allowed, the Paris and Rouen line being pledged to be opened throughout in 1842, but all was ready, to the satisfaction of the Directors, of Mr. Locke, and of the French Government. Soon after the opening, Messrs. Allcard, Buddicom & Co. contracted to work the line, furnishing locomotive-power, and repairing the carriages and wagons on the principle of the prime cost of the stock being borne by the railway company, but the contractors paying for its depreciation at the expiration of the contract. Every other expense relating to locomotive-power, or repair of wagons and carriages, including responsibility for accidents caused by the fault of engine-drivers or others in their employ, remained with the contractors. This arrangement was extended to the Havre and Rouen line when it was opened in 1843, to the Fécamp, the Mantes and Caen, and the Caen and Cherbourg lines, a total length of 390 miles, and continued in force till the end of 1860. The repairing-shops were built at Sotteville, near Rouen. In 1845 Messrs. Allcard, Buddicom & Co. abandoned the Chartreux works, and built more suitable ones adjoining those of the railway at Sotteville, the company agreeing to purchase the contractors' premises at the end of the contract, should the latter wish to dispose of them.

It was during the early days of the Paris and Rouen line that the extension of railways began in France, and Mr. Buddicom had at the time much to do with the supply of rolling-stock then. Mr. William Mackenzie had undertaken to complete the works of the Orleans and Tours line, and to provide the engines and

rolling-stock. This work was entrusted to Messrs. Allcard, Buddicom & Co. They also supplied the engines required for the Boulogne and Amiens Railway, the nucleus of the great system now belonging to the Northern Railway of France. When the concession for the Paris and Lyons Railway was granted, the capital was not forthcoming, and the successful company applied to Mr. Buddicom's firm to take a large number of shares, to be paid for, if they chose, in locomotives. These terms were accepted, and the aid thus afforded in floating the company was, at the least, very useful. In the sequel, the company being successful, Mr. Buddicom waived the right to supply these engines, the Rouen works at the time being fully occupied. In 1849, having contracted with the Southern of France Company for a quantity of rolling- and fixed stock, Messrs. Allcard, Buddicom & Co. erected branch works at La Bastide, near Bordeaux, introducing thereby an entirely new trade into the district. Thus, out of the six great companies, among whom the French railway system was divided, Mr. Buddicom supplied the first engines for four, and might have done, had he so willed, for five. In this connection may be mentioned a fact that is very significant of the part taken by Englishmen in the construction of the French railway system. The "rule of the road" in France is the converse of that which obtains in England, carriages and horsemen keeping to the right; but when the French railways were made the English contractors introduced their own national use in this respect, and to this day French trains take the left on double lines and on the crossings of single ones.

In 1848, when the Revolution broke out in France and all over the Continent, very great difficulty was experienced from the communistic principles of the working classes. These were opposed to all contracts, condemning them as being "*l'exploitation de l'homme par l'homme*"—a popular cry which was the cause of greatly exciting the working classes against heads of establishments, and, more especially, if, as in the case of the Rouen Railway Works, the heads were not Frenchmen. The Northern Railway, the St. Germain, the Versailles, the Paris and Orleans, and all other lines, with the exception of the Paris and Rouen and Havre system, had been taken possession of by the Clubs, and were actually worked, as far as regards the locomotive power and rolling-stock, under the orders of one of them specially composed of the men employed on the railways. With the greatest difficulty Mr. Buddicom succeeded in escaping from these influences, or more properly speaking, in delaying their interference. Some

of his men, both French and English, stuck to their duties and personally protected him on several occasions, enabling him to carry on a small service of trains, and stem the interference which had caused such confusion and mischief in other directions. On the Paris and Orleans line the manager of the station and workshops had been shot by his own people. But the crisis came at last, the clubs sending a deputation to the Directors of the Paris, Rouen and Havre Companies to communicate their orders, which were to the effect that Messrs. Allcard, Buddicom and Co.'s contracts were to be at once broken, that the working of the railway was to be handed over to the persons to be nominated by the clubs, and that Mr. Buddicom and all the English and other foreigners employed were to cease to be connected with the railway, and to leave the country. Mr. Buddicom was summoned by the Board of Directors to attend the meeting, and received great personal abuse from the delegates of the club, as well as open threats of assassination if he hesitated to act in accordance with the decision of the club. Just when the language of the delegates became most violent, word came to the Directors that the Chamber of Deputies had been taken possession of by the mob. The excitement which this created caused the delegates to become more and more abusive towards him. Some of them and some of the Directors left the room. The meeting ended by a proposition from the manager of the railway, Mr. de Laperière, or the Secretary, Mr. Thibaudeau, that a general Board of Directors should be called for the following day to receive the communication made by the delegates, and that the decision of the Board should be communicated to the club authority immediately afterwards. During the night the political position was altered completely. The party of order gained the upper hand; the delegates did not show themselves on the following day. Mr. Buddicom consequently held his ground, and continued to work the railways, not merely those included in the firm's contract, but helped the Versailles line to convey the traffic for one of the "great fountain" days with engines lent by the Paris and Rouen Company, the service of the Versailles Railway having been entirely disorganized by the action of the clubs.

From this period the authorities were enabled to give the works at Sotteville and Mr. Buddicom personally the necessary protection. He had special police service told off for this purpose, and on more than one occasion received instructions not to expose himself. He also received special authorization from the Prefect of the Seine to carry arms, and use them, if need be.

It may here be mentioned that when the Revolution broke out in February 1848, the dregs of Rouen—at that time a number of ticket-of-leave men who were residing there under the supervision of the police—visited Sotteville works (after setting fire to the wooden bridge carrying the Havre line over the Seine), with the declared purpose of burning the rolling-stock, being encouraged by the boatmen on the river, whose work had been seriously affected by the railway. The night was a memorable one, storm and rain intensifying the emotions caused by the sight of the blazing bridge. There was no protection from any one but a few resolute French workmen and clerks, as the English workmen were advised by their comrades in the works to keep out of sight. Several of these men formed themselves into a sort of body-guard to protect Mr. Buddicom, and one man in particular heated some irons in one of the fires, and facing the crowd of mischief-makers, vowed destruction to any one who attempted to harm Mr. Buddicom. These hot irons had a wonderful effect, and though torches were lit, and bottles containing spirits of turpentine were prepared to quicken the fire, the idea was abandoned, thanks to the exertions of the workpeople. A curious argument of one of the rioters to the effect that the works would, if burnt, throw many out of employment, whereas the burning of another bridge crossing the Seine a few miles distant, and belonging to the Railway Company, would meet the case, also had its effect, the animosity being against the railway and not against Messrs. Allcard, Buddicom & Co. This proposal was received with approval, and a party started with the proposer to carry out the project. The night became so wet that the party dispersed before reaching the bridge, and all was safe. The following nights the firm's employees formed among themselves a regular body of protectors to the works, and prevented any mischief being done.

On the first night of the outburst attempts had been made to break the doors of Mr. Buddicom's house in the works, but without success, the only mischief done being some broken windows. In the early morning he got his wife and two daughters to his father-in-law's house, whence in a few days they proceeded to England.

Among other matters which occupied him much during the three first days of the Revolution was the anticipated arrival at Sotteville of the King, who was endeavouring to escape from France. A special messenger had come to Mr. Buddicom from Paris requesting him to be ready, if need be, for a dash in the

direction of the coast, and he necessarily had to be prepared for such an event without allowing any one to know that such a visit was even possible. The King escaped by another route, as is well known. A period of great bodily and mental fatigue was passed, when there arose other difficulties of a nature Mr. Buddicom had not previously had to contend with. The gentleman at the head of the mercantile part of the business went away, leaving him alone to contend with financial troubles of a very serious nature. It had been the custom of several of the railways for which they were working to make their payments in bills payable not earlier than three months after date, which were discounted without the slightest difficulty by the Bank of France, being considered first-class paper. In consequence of the disorganization which followed the February days, and the mischief done to bridges and other portions of the railways, particularly on the Paris and Rouen and Havre and St. Germain lines, traffic was suspended, and necessarily receipts were nearly nil, the results being that the bills as they matured could not be met by the Companies, and Messrs. Allcard, Buddicom & Co. had, as drawers of these bills, to arrange with the people into whose hands they had come in the course of business. This state of things necessarily created great anxiety, especially as at the same time their bankers suspended their payments. It was absolutely necessary to provide funds for a large number of workpeople, who otherwise would have been thrown out of employment, and many of whom would, in all probability, have joined the band of disaffected instead of protecting the works. The men and employees were all put on short time, and became very reasonable when they saw the difficulties which had to be encountered, and how much better their wants were provided for than those of the greater portion of the other workpeople of the neighbourhood of Rouen.

The difficulties were increased by the great scarcity of specie wherewith to pay wages. Great exertions had to be made to overcome this trouble. Interviews with members of the Revolutionary Government were necessary to obtain even very small amounts from the Bank of France and its branches in exchange for notes. It was even necessary to present proofs that the change was to be exclusively used for wages, and generally a very insufficient quantity was given, necessitating paying several men together with bank-notes. The immense service rendered to business people by the prudent action of the Bank of France can only be appreciated by those who had to struggle with the serious financial difficulties experienced by employers of labour, and generally by

those in business. Mr. Buddicom met with the greatest consideration. The Bank had discounted a large amount of the railway companies' paper, and also other paper bearing the firm's signature. On the authorities being informed of the inability to meet these engagements, and the offer being made to submit the books of the concern for inspection in proof of this statement, the position was fully appreciated. Mr. Buddicom was informed that the Bank, knowing that the bills were legitimate ones, and that their drawers were in no wise responsible for the financial difficulties in which they were placed, desired him to use all endeavours to keep the workmen employed, and the traffic on the railways, such as it was, from being interrupted, assuring the firm that every latitude possible should be given in respect of the bills for which they were liable. Mr. Buddicom was told not to cripple their resources, as the Bank of France was perfectly satisfied to wait. Had this policy of waiting not been adopted as its general policy by the National Banking Establishment, the financial catastrophe in France would have been far greater.

Shortly after the Coup d'État in 1852 business confidence was restored, and a period of prosperity for France set in. About this time Mr. Buddicom's partner, desiring to diminish his responsibility in the concern, and having lost some of his confidence in French operations, withdrew from the firm. A new partnership was formed, Mr. Buddicom alone being director, under the title of "Buddicom and Co." This arrangement continued unchanged till the expiration of the partnership in 1860. During this period he was actively connected with other matters in France, in Germany, in Italy, and some in England. In 1854, jointly with Messrs. Parent and Shaecken, the extensive Belgian contractors, and Mr. Brassey—Parent, Brassey and Buddicom—a contract was made with the Lyons and Geneva Railway Company for the execution of the Bellegarde Tunnel on that line, the length something more than 4,000 metres. In 1860 Mr. Buddicom formed one of a party, of which Mr. Brassey and Mr. Charles Jones were the leading spirits, for the construction and stocking of the Maremma Railway, completed in 1865. In 1860, jointly with Mr. Brassey, he undertook the work of doubling the Rouen and Dieppe line, and rebuilding a number of the bridges over the river in the valley, and in 1863 formed part of the company Brassey, Parent and Buddicom, contracting for the execution of a portion of the Southern Railway of Italy. Owing to circumstances the execution of these latter works was confided to a branch of the house of Parent, Shaecken and Co., the con-

tractors, but the financial operations remained at the charge of the original contractors. The winding up, however, devolved on Mr. Buddicom, owing to the death of Mr. Parent, followed by that of Mr. Brassey. During this period, Mr. Buddicom was busily occupied, as one of the directors of an extensive colliery in the neighbourhood of Marseilles, jointly with Mr. Brassey, Mr. Blount and others. Also as one of the directors of a colliery company in the Prussian Rhenish provinces, and in a similar position connected with the Société des Polders de l'Ouest for reclaiming an extensive tract of ground in the Baie de St. Michel on the Brittany coast, and in the Baie des Veys on the coast of Normandy. At the termination of the contracts for working the various railways alluded to, which had been merged into one company, the Western of France, the company claimed their rights of taking possession of the Sotteville works, including the portion belonging to Buddicom and Co., as well as the tools, &c. Thus the firm ceased to exist, and Mr. Buddicom abandoned the business of an engineer. After residing some time in Paris he took up permanent residence at Penbedw, North Wales, retaining merely in France his connection with the Société des Bouches du Rhône, that of the Mengede Colliery, the Polders de l'Ouest, the Society Brassey, Parent and Buddicom, and his connection with the banking-house of Edward Blount and Co. of Paris.

Previous to 1860 Mr. Buddicom was for a time a Director of the Dublin and Meath Railway, and of the Hereford, Hay and Brecon Railway. He was also a Director of the Central Argentine Railway and the Central Argentine Land Company, remaining connected with them till some time after the completion of the former and organization of the Land Company. He was a Magistrate for the County of Flint, and served as High Sheriff in 1864.

From the time of his return to England his career was an uneventful one, and he never ceased to regret that he so early severed himself from the profession.

Mr. Buddicom was elected a Member on the 3rd of June, 1845.

WILLIAM AUBONÉ POTTER, who died on June 20th, 1887, was born at Cramlington, Northumberland, in October, 1832. He was the eldest son of Mr. Edward Potter, M. Inst. C.E., an eminent north country mining engineer. At the early age of four years he was sent to a ladies' school, then to the Rev. Isaac Todd's, next to Bramham College, and eventually to King's

College, London, which last he quitted in 1850, to serve an apprenticeship of five years to his father, who was viewer at Cramlington Collieries. Here the younger Potter remained assisting his father, until 1855, when he was appointed viewer to Messrs. Day and Twibell, of Monk Bretton, Barnsley, Yorkshire, where he had under his charge, in the first instance, the Mount Osborne and the Old Mill collieries. He afterwards sank the Agnes Pit for Mr. Day, and thus formed another drawing-shaft. In March, 1857, the explosion (memorable in the Barnsley district) at Lundhill Colliery, happened. The pit, taking fire, had to be filled with water, and, after it was drawn, Mr. Potter, Mr. Ralph Maddison, Mr. Thomas Cowper, Mr. John Brown, and several other mining engineers were specially intrusted by the late Mr. Nicholas Wood, the late Mr. Thomas Forster, and Mr. (now Sir George) Elliott, the consulting engineers, with the responsibility of clearing the pit and exhuming the one hundred and ninety-seven victims of the disaster—a long, arduous, and dangerous work. Mr. Potter also undertook the work of restoring ventilation to the mine, which occupied a period of three months, and was carried on in addition to the discharge of his ordinary business. On the 8th of December, 1862, an explosion occurred at the Edmund's Main Colliery, when Mr. Potter again distinguished himself by his exertions and practical advice. On the 17th of that month, Mr. Potter and another engineer were preparing to go down and explore, when a friend (Mr. Embleton), riding past at the time, warned them against doing so, having been taught by former experience that another explosion would in all probability shortly ensue; the warning was scarcely given before it was verified. In 1863 Mr. Potter sank the New Sovereign Pit and the pumping-shaft for Mr. Clarke, of Noblethorpe, near Barnsley, of whose collieries at Silkstone and Dodsworth he became viewer and manager. The greatest mining disaster Mr. Potter was associated with was that at the Oaks Colliery, in 1866. After the explosion, he, together with many other explorers, was quickly on the scene ready to descend, when an urgent message for him to repair on the instant to the upcast shaft of the mine saved his life; all the others (thirty-two), who had, like himself, volunteered to explore, being killed by a second explosion, which was so violent in its effects that Mr. Potter and others, standing at the pit-brow, were thrown to the ground.

Whilst living in Yorkshire Mr. Potter took an active part in the volunteer movement, then in its infancy, and, when in 1860 the 37th West Yorks Rifle Volunteer Corps was founded, he was

appointed one of its first commissioned officers; he was well up in his drill when he joined this corps, having before served in the Northumberland militia.

Mr. Potter and Mr. Embleton together founded the Midland Institute of Mining and Mechanical Engineers, the former acting as secretary. This Institute was the outcome of a smaller society called the Yorkshire Miners Association, of which Mr. Potter was the organizer.

In 1868 Mr. Potter reluctantly resigned his Yorkshire appointments, wherein he had had the charge of two thousand men, and returned to Northumberland. This step was taken at his father's earnest request, whose failing health made him desirous that his son should take his place as viewer at the Cramlington Collieries, in which he and his family had a large interest. Before leaving Barnsley Mr. Potter's friends in the district gave him a service of plate—a tangible token of their esteem and affection—and he left the spot, where he spent the happiest and busiest years of his life, regretted alike by his employers, his friends, and also the miners, who looked upon him as their friend as well as master. On his return to the North, Mr. Potter continued to give the same unremitting attention to the duties of his profession which had characterized him in Yorkshire. He was a Justice of the Peace for the Borough of Tynemouth and the County of Northumberland, and also a River Tyne Commissioner. He held, too, the appointment of Government Check Viewer for the Greenwich Hospital Estate. In 1875 he was elected Mayor of Tynemouth, and gave general satisfaction whilst holding that office, for which his genial manners and liberal hospitality alike fitted him.

More than a year ago Mr. Potter's health broke down, and he was for many months under medical care. Latterly he improved so much that hopes were entertained of his ultimate recovery; but a relapse set in, producing nervous exhaustion, which proved fatal. He was buried in Cramlington Churchyard; his friends gathered round his grave, anxious to pay their last tribute to one who, by his straightforward and exemplary conduct in life, had endeared himself to all with whom he came in contact.

He was elected a Member of the Institution on the 7th of May, 1867.

THOMAS STEVENSON, fifth son of the well-known Lighthouse Engineer, Robert Stevenson, M. Inst. C.E.,¹ was born at Edinburgh on the 22nd of July, 1818. He entered his father's office before he had completed his eighteenth year, and after serving a regular pupilage and superintending the execution of various works, he was taken into partnership by his brothers Alan² and David³ in 1846. His firm was chiefly engaged in the construction of harbour, dock, river, and lighthouse works. With most rivers and harbours in Scotland, he and his partners were in some way professionally connected, while they were also called upon to design works for the improvement of many rivers and harbours in England and Ireland. In 1855 Mr. Stevenson was conjoined with his brother David, as Engineers to the Northern Lighthouse Board, and the firm designed and erected 28 lighthouses, two of them—Dhu Heartach,⁴ and the Chickens Rock—being works of no ordinary difficulty.

Being the junior member of the firm, he was enabled through life to devote a large portion of his time to investigations of various kinds. Thus to the subject of harbour construction, Mr. Stevenson early directed his attention, bestowing special care on ascertaining the forces which have to be met and overcome in the erection of works exposed to heavy seas in deep water. He devoted special attention to ascertaining the force, height, and laws of propagation of sea-waves, and their action on artificial structures. The measurement of the force of waves was carried out with some completeness by means of instruments of his own device. The results of his wave-observations, and the laws deduced from them, were given in papers communicated to the Royal Society of Edinburgh, and to the Edinburgh Philosophical Journal, and in his book on "Harbours."⁵ In 1852, after a series of experiments, he enunciated the law of the increase of the height of waves in relation to fetch; other experiments led to formulas, involving the relations between the heights of waves, and the various influences which modify them, and also to formulas, by which the reductive power of harbours and breakwaters could be calculated, all of which are of considerable value to the marine engineer. He always held, however, that much remained to be done, especially in ascertaining facts, and he

¹ Min. Proc. Inst. C.E. vol. x. p. 94.

² *Ibid.*, vol. xxvi. p. 575.

³ *Ibid.*, vol. lxxxvii. p. 440.

⁴ *Ibid.*, vol. xlv. p. 1.

⁵ "The Design and Construction of Harbours." A treatise on maritime engineering. By Thomas Stevenson, P.R.S.E., F.G.S. Third edition. Edinburgh, 1886.

considered his own work in this direction as only an approximation. About thirty years ago, he wrote the article "Harbours" for the "Encyclopædia Britannica," which was subsequently published as a separate treatise on "The design and construction of Harbours,"¹ and it is now in its third edition.

To lighthouse optics, Mr. Stevenson devoted special consideration, and devised many notable improvements, both in catoptric and dioptric apparatus. It may be sufficient to state among other improvements, the holophotal system—the condensing system for fixed, revolving and intermittent lights; the dioptric spherical mirror, and the apparent light. In designing these improvements, he was ably assisted by Mr. Alan Brebner, M. Inst. C.E. For a great many of the Scottish Lighthouses, the optical apparatus is of a novel design to suit the special requirements of their situations, the latest being the condensing flashing apparatus, for the Isle of May Electric Light. In his book on "Lighthouse construction and illumination,"² which has passed through three editions, the results of the practice of his firm in lighthouse construction and optics are given. For some of his inventions, laid before the Royal Scottish Society of Arts, Mr. Stevenson was awarded their gold medals. At the French Exhibition of 1878, his merits as an inventor in lighthouse optics were likewise recognised by a gold medal. His firm's advice was taken by the Governments of India, Newfoundland, New Zealand and Japan, and schemes for lighting the whole coasts of the two last countries were devised by them, and are now being carried out.

To meteorology, Mr. Stevenson early devoted his attention. From 1842, when he wrote a paper on "Defects in Rain Gauges," his interest in meteorology has never flagged, many papers being written on different branches of the subject. He introduced the use of barometric gradients, as a step towards the numerical measurement of the intensity of storms; and he devised the useful screen for the protection of exposed meteorological instruments, now in very general use, as it rendered observations made at different places comparable with one another. From the inception of the Scottish Meteorological Society he keenly advocated its interests, and took an active part in all its operations, particularly the establishment of the high-level Observatory at Ben Nevis.

Mr. Stevenson was a devoted member of the Church of Scotland. Under the pseudonym of a "Layman," he wrote several pamphlets

¹ *Ante.*

² "Lighthouse Construction and Illumination." By Thomas Stevenson, F.R.S.E., F.G.S. London, 1881.

on religious questions, one of which was reprinted by the late Professor Crawford for the use of his students. He did much in unostentatious charity, all deserving institutions finding in him a warm and generous supporter.

Mr. Stevenson was incapacitated for business for some time previous to his death. He spent last winter at Bournemouth, returning to Edinburgh a fortnight before his death, which took place on the 8th of May, 1887.

As will have been already noticed, Mr. Thomas Stevenson came of a family of engineers, all of them highly distinguished in the profession, and of whom five have been members of the Institution. Both in professional and private life he was greatly esteemed and respected. He was elected a Fellow of the Royal Society of Edinburgh in 1848, acted as a member of Council, as one of its Vice-Presidents, and in 1885 was elected its President. He was elected a member of the Institution on the 2nd of February 1864, and one of his last literary undertakings was the lecture on "Tides and Coast Works," read on his behalf on the 16th of April 1885, he being unable from indisposition to be present. He was a Fellow of the Society of Antiquaries of Scotland, the Geological, and other societies.

MARIOTT OGLE TARBOTTON, the son of a merchant of Leeds, was born in that town in December, 1832. He received his education at Leeds Grammar School, and early manifesting a taste for engineering, was articled to Mr. Charles Clapham, Civil Engineer, of Wakefield. To this gentleman's practice he ultimately succeeded, and in 1855 he received the appointment of Borough Surveyor at Wakefield. While here, he designed and erected the new and elegant Parish Church of St. Mary's. In 1859 he was appointed Borough Engineer to the Nottingham Corporation. In Nottingham, he found a full field for the display of the abilities he possessed. The town was then in a state of transition as regarded sanitary and engineering works; for the Public Health Act had just been put into force, and a strong hand was needed to change the old order, and to inaugurate an entirely new system. There had previously existed a number of local boards, each separate from, often jealous of, and invariably acting independently of each other, while the Road-Surveyor was practically the Chairman of the Highway-Committee. Mr. Tarbotton's task was to evolve order from this chaos. He was not long in remodelling the whole system, and in so reorganizing it

as to get a thorough control over the work of his department. His subsequent history is the history of the development of Nottingham from an insignificant borough into a prominent and enterprising town. After his labours for the purification of the lower-lying parts of the town had been successful, Mr. Tarbotton set about a work of the utmost importance—the designing and erection of a new bridge over the Trent, to replace the quaint old many-arched structure which contributed so much to the flooding of the Meadows. In 1867 he submitted his plans and estimates for a new bridge, which were adopted by the Town Council. In 1869 the memorial stone was laid with much rejoicing, and in 1871 the bridge was opened, having cost over £31,000. The new work permits the flood-waters to pass freely through, rendering it a great boon to the dwellers in the Meadows. In 1876 he spanned the river at Gunthorpe with a smaller bridge.

Nottingham is said to have been the first place after London to adopt subways beneath the main streets. In 1865, Mr. Tarbotton set about the construction of the subways in Victoria and Queen Streets, where the drains and gas- and water-mains are laid. Later on he provided similarly for the sewers and telegraph wires. Further work in the same direction has been carried out by the present Borough Engineer, Mr. Arthur Brown. The question of dealing with the sewage, not only of Nottingham, but of the whole Leen Valley, was the next to engage Mr. Tarbotton's attention, and on this subject he laid before the Town Council an elaborate report which led to the passing of the Leen District Sewerage Act, 1872. Under that Act the Leen District Sewerage Board was established. Mr. Tarbotton was engineer to the Board, and laid down the central sewerage system which still drains the Leen Valley. In 1875 Mr. Tarbotton presented a report which embodied a scheme for concentrating between Long Row and Parliament Street, on the site of the present Exchange Hall, or between North Street and Parliament Street, blocks of buildings which should comprise municipal offices, Town-Hall, Museum, and Free Library. That report was withdrawn, but it led to the subsequent development of the scheme for the erection of the University College in Horse-Fair Close. Before the college was decided on, Mr. Tarbotton reported as to its cost and size, detailed the rooms which it should contain, and made drawings which determined the plans finally adopted.

In 1874 the undertaking of the Nottingham Gas Company was taken over by the Corporation, and he was called on to assume control of the works. These now cover a larger area than any

others in the kingdom, having been greatly extended under Mr. Tarbotton's directions. In 1879 the waterworks were also acquired and placed under his management. It was felt that, with the large gas- and water-undertakings on his hands, Mr. Tarbotton could no longer be expected to carry on the work of Borough Engineer, so Mr. Arthur Brown, M. Inst. C. E., was appointed to the latter post, and Mr. Tarbotton was retained as Consulting Engineer to the Corporation, and engineer to the Gas- and Water-Departments and the Sewage-Farm Committee. In 1878 the Nottingham Waterworks Company obtained an Act of Parliament to extend their limits of supply and to construct new works at Papplewick. They had agreed with the owners of the Papplewick Estate for land for a reservoir and engine-house and for the right to sink for water. One of the districts (Hucknall Torkard) which they desired to include was struck out of the Bill on the opposition of the local board of Hucknall. As it was necessary to pass through this district, fresh parliamentary powers were sought in 1879. In the same year an agreement was entered into between the company and the corporation of Nottingham for the sale and purchase of the undertaking, and the Act authorising the transfer to the corporation was passed. The pipe lines and Papplewick reservoir were completed for the company by Mr. Hawksley, Past-President Inst. C. E., their Engineer, who also prepared the specification and plans for the engines, engine-house and well. These were approved by the directors before the date of transfer, and the construction of the works would have been proceeded with, but Mr. Hawksley advised the company to await the issue of the negotiations with the corporation. When the corporation took possession of the undertaking Mr. Tarbotton got out fresh plans and specifications from which the existing engine-house and engines were constructed. The reservoir at the top of Park Row was extended and completely covered in by him, the operations in connection with which change were at the time illustrated and described in *The Engineer*.¹ In 1884 he constructed the covered reservoir on Mapperley Hill. Amongst Mr. Tarbotton's latest works of note should be mentioned the Eastcroft pumping-station, for supplying the sewage-farm, which he barely lived long enough to see started. In 1877 Mr. Tarbotton was called on to give evidence before the Duke of Richmond's Commission as to the conservancy of rivers.

In addition to the works which Mr. Tarbotton was called upon to execute for the Corporation of Nottingham, he was frequently

¹ *The Engineer*, 10th July, 1885.

engaged as a consulting engineer in various parts of the country, principally in connection with sanitary engineering and waterworks. In this way he was employed at Eton College, Uppingham School, and Belvoir Castle, at which places he devised and carried out schemes of drainage. Just before his death, he was called upon to adjudicate on the plans for an important undertaking in the North of England, and this was the only work he left unfinished. He had completed all the new buildings he had in hand for the Corporation. The Eastcroft Sewage-pumping Station was set in operation the Monday before he died, and the Papplewick Waterworks was completed a week or two earlier. He attended a meeting of the Sewage Farm Committee on Friday, March 4, 1887, but was scarcely able to speak. At a later hour he was taken home partially paralysed; rallying he endeavoured to transact business on the following day, but he died on the 6th.

His colleagues assert that during his long connection with Nottingham he never gave himself adequate rest or recreation, and that his mind was generally occupied with engineering or architecture during the short holidays which he was induced to take. Loss of memory, and symptoms of nervous disorder had occasionally manifested themselves during the past two years.

Mr. Tarbotton was elected a Member of the Institution on the 1st of April, 1862. He was also a Fellow of the Geological Society and a Fellow of the Royal Meteorological Society. In meteorology he took much interest, and for years he has made important detailed observations, of which reports have been published at short intervals. Few engineers have left behind them such artistic memorials, for Mr. Tarbotton took care that all his structures should be fitly and gracefully decorated. He was by nature both artist and engineer, and felt deeply the sentiment of any work on which he was engaged. He was an accomplished scholar, full of classical lore, and a refined gentleman, kindly and genial in the last degree; on account of which qualities he is more deeply regretted by his friends than for his manifest and great abilities.

JOSEPH WHITWORTH was born at Stockport on the 21st of December, 1803. His father, Charles Whitworth, was a schoolmaster; his mother was a daughter of Mr. Joseph Hulse. At his father's school Joseph Whitworth received his early education. When twelve years old he was sent to the school of a Mr. Vint, at Idle, near Leeds, where he remained a year and a half. His

uncle was a cotton spinner in Derbyshire, and at the age of fourteen young Whitworth was sent to learn the business. He had a decided taste for mechanics, and during the four years he was under his uncle he mastered the construction and working of every machine in the place, so that there was none which he could not make or mend. But his taste was too strong for the arrangements his relations wished to make for his future. He made up his mind to be a mechanic, and in 1821 went to Manchester to work in the mechanics' shop of Messrs. Crighton & Co. His first ambition was to be a good workman, and he often in later years said that the happiest day he ever had was when he first earned journeyman's wages.

In 1825 he married Fanny, youngest daughter of Mr. Richard Ankers, and shortly afterwards came to London, to the workshop of Messrs. Maudslay. He soon won a position as one of the best workmen, and while here he made his first great discovery, which consisted in the mode of construction of a set of perfect plane surfaces. Up to that time the most accurate planes had been obtained by first planing and then grinding the surfaces. They were never true, and young Whitworth became possessed with the idea of making a true plane. At the next bench sat a Yorkshireman named John Hampson, a good workman and a good fellow, who took an interest in his young companion's work. One day as they worked Whitworth ventured on an idea. "If these planes were true, one of them ought to lift the other." "Tha knows nowt about it," was the cynical reply of steady-going experience. Whitworth kept on at his problem, working quietly at his lodgings. His first step was to abandon grinding for scraping. "Taking two surfaces," he said, when telling the story afterwards, "as accurate as the planing tool could make them, I coated one of them with colouring matter and then rubbed the other over it. Had the two surfaces been true, the colouring matter would have spread itself uniformly over the upper one. It never did so, but appeared in spots and patches. These marked the eminences, which I removed with a scraping tool until the two surfaces gradually became more coincident."

But while his skill as a workman was thus being made the most of, Whitworth's mind was not idle. He saw that his first thought was not enough. Two surfaces might lift each other by fitting perfectly and yet not be true planes. One might be convex and the other concave. A new light came. Make three surfaces. If each will lift either of the others they must be planes and must be true. After another stage of skilful labour

the three planes were made and the test fulfilled. The Sunday after the problem was solved Whitworth called on his old mate. "John," said the young man, "come to my house; I've something to show you." The true planes were exhibited. "Ay! tha's done it," said John. That was probably the greatest moment in a great life. Joseph Whitworth had perceived that a true plane was the first thing needed for the improvement of mechanical construction. He set to work to produce it, and by sheer clear thinking and honest work he did produce it. The invention was characteristic of the man. It was an ideal of perfection first conceived as desirable, and then once for all finally and absolutely realised. This is the distinguishing mark of Whitworth's genius. Having once seen a want, and having grappled with the problem, he thought the matter out and solved it.

On leaving Maudslay's, Whitworth worked at Holtzapffel's, and afterwards at Clement's, where Babbage's calculating machine was at that time in process of construction. In 1833 he returned to Manchester, where he rented a room with steam power, and put up a sign "Joseph Whitworth, Tool Maker, from London," thus founding a workshop which soon became and has to this day remained the model of a mechanical manufacturing establishment.

In 1840, at the meeting of the British Association, held in Glasgow, Whitworth read a Paper on "Plane Metallic Surfaces, and the Proper Mode of Preparing them," in which, besides explaining in detail the method employed in the preparation of true planes, he pointed out some of the departments in which their application was destined to prove of incalculable value. "A true surface," he said, "instead of being in common use, is almost unknown; few mechanics have any distinct knowledge of the method to be pursued for obtaining it; nor do practical men sufficiently advert either to the immense importance or to the comparative facility of the acquisition. . . . The want of it in various departments of the arts and manufactures is already sensible. The valves of steam engines for example, the tables of printing presses, stereotype plates, surface plates, slides of all kinds, require a degree of truth much superior to that they generally possess. In these, and a multitude of other instances, the want of truth is attended with serious evils. . . . The extensive class of machinery denominated tools affords an important application of the subject. Here every consideration combines to enforce accuracy. It is implied in the very name of the planing engine. The express purpose of that machine is to produce true surfaces, and it is itself constructed of slides, according to the

truth of which will be that of the work performed. When it is considered that the lathe and the planing engine are used in the making of all other machines, and are continually reproducing surfaces similar to their own, it will manifestly appear of the first importance that they should themselves be perfect models."

Whitworth seems to have set before himself from the beginning an ideal of perfection in mechanical construction beyond the wildest dreams of his early contemporaries. The true plane rendered possible an accuracy which was a new thing in the mechanical world. The next step was to introduce a system of measurement of ideal exactness. At the time referred to, a good workman had done well if the shaft he was turning or the cylinder he was boring was "right to the $\frac{1}{32}$ of an inch." This was, in fact, a degree of accuracy as fine as the eye could usually distinguish. Whitworth felt that it was altogether inadequate, and resolved to trust to the sense of touch. If two plugs be made fitting into a round hole they may differ in size by a quantity imperceptible to the eye or to any ordinary process of measurement; but in fitting them into the hole the difference between the larger and the smaller is felt immediately by the greater ease with which the smaller one fits. In this way a child can tell which is the larger of two cylinders differing in thickness by no more than $\frac{1}{1000}$ of an inch. It was to this perception of differences by comparison with a standard through the sense of touch that Whitworth appealed. Standard gauges, consisting of a hollow cylinder and a pair of solid cylinders to fit but differing in diameter by the $\frac{1}{1000}$ or the $\frac{1}{10000}$ of an inch, were given to his workmen, with the result that a degree of accuracy inconceivable to the ordinary mind became the rule in the shop. To measure these minute differences was a harder matter. A child, it has been said, can tell which of the two cylinders fits the hole the more loosely and is therefore the smaller. But by how much do the diameters differ?

To ascertain this, and indeed to render the construction of the gauges possible, Whitworth made his *measuring machine*, which is an application of his first work, the true plane. A system of planes is arranged so that of two parallel surfaces the one can be moved nearer to or further from the other by means of a screw. The turns of the screw measure the distance over which the moving plane has advanced or retired. Suppose, then, a bar of steel is placed between the two surfaces, and the moving surface is advanced until the two surfaces hold the bar and prevent its falling. Experience shows that the bar will fall if the distance

between the surfaces is increased by an incredibly small amount. Thus in the machine used in the Whitworth workshop the screw has twenty threads to an inch. It is the axle of a large wheel divided along its circumference into five hundred parts. If, then, the wheel be turned one division, the movable surface is advanced or retired by $\frac{1}{500}$ of a turn of the screw—that is, by $\frac{1}{10,000}$ of an inch. This slight difference is at once perceptible at the bar between the surfaces, for it makes the difference between the bar being firmly held and its dropping. Some of Whitworth's measuring machines have gauged in this way fractions smaller than the millionth of an inch.

In the year 1841 Whitworth read at The Institution of Civil Engineers, a Paper on "An Uniform System of Screw Threads."¹ At the time when he began his career as a manufacturer, the screws used in fitting up steam engines and other machinery appear to have been manufactured without any system. There was no rule regulating the proportionate strength of the thread and centre part of the screw, nor settling either the pitch, the depth, or the form of the screw thread. Whitworth perceived the advantages which would arise from uniformity of system. He made an extensive collection of screw-bolts from the principal workshops throughout England, and in this way ascertained the average dimensions of the screws in common use. Upon this basis he established his system of screw threads, which had already in 1841, been adopted exclusively on many of the railways, and in some of the most extensive engineering establishments in England and Scotland. Seventeen years later he was able to record the universal adoption of the system he had recommended.

In 1842 Whitworth produced a street-sweeping machine, which, after being in operation for ten months in Manchester, was reported to have changed that town from one of the dirtiest into one of the cleanest of the large English towns. The apparatus consisted of a series of brooms attached to two endless chains running over an upper and a lower set of pulleys, which were suspended in a light frame of wrought-iron behind a cart. As the cart wheels revolved they gave a rotatory motion to the pulleys carrying the endless chain, and the series of brooms attached to them, which, being made to bear on the ground, successively swept the surface, and carried the soil up an incline over the top of which it dropped into the cart. The machines were for some time in use in Manchester, Newcastle, and Birmingham, and were considered to be cheaper,

¹ Minutes of Proceedings p. 157 Inst. C.E. vol. i. (1841).

more efficient, and more convenient than hand labour. He presented a description of this apparatus to the Institution.¹

Between 1840 and 1850 Whitworth invented and patented a number of new machines, of which the most important were the duplex lathe, and the reversing tool of the planing machine.

The Great Exhibition of 1851 gave Whitworth his true place in the public estimation, for the remarkable collection of engineers' tools, and of his various inventions which he there brought together—among them the measuring machine—gained him the reputation of being the first mechanical constructor of the time.

In 1853 Whitworth was appointed a member of the Royal Commission to the New York Industrial Exhibition. The incomplete state of the machinery department prevented his reporting upon it, and the special report which he drew up after his return to England embodies the results of observations made in the course of a journey through the industrial districts of the United States. The details of this report have now probably only a historical interest, but some of Whitworth's general conclusions deserve to be permanently recorded. "The labouring classes," he wrote, "are comparatively few in number; but this is counterbalanced by, and indeed may be regarded as one of the chief causes of the eagerness with which they call in the aid of machinery in almost every department of industry. . . . It is this condition of the labour market, and this eager resort to machinery, wherever it can be applied, to which, under the guidance of superior education and intelligence, the remarkable prosperity of the United States is mainly due."

In 1856, Whitworth was President of the Institution of Mechanical Engineers, and during the meeting at Glasgow delivered from the chair an address in which most of his favourite ideas are briefly explained. He sets out from the want which probably at that time was his principal difficulty of "iron of great strength free from seams, flaws, and hard places." It was to the production of such a material that he looked to escape the error of excessive size in the construction of the moving parts of machines. "It should be," he said, "an axiom in mechanics, that whatever has motion should be as light as circumstances will admit." Having called attention to what he considered the two great elements in constructive mechanics—the true plane, and the power of measurement—he proceeded to discuss the question of proper gradations of size in all the various branches of the mechanical arts. "I think,"

¹ Minutes of Proceedings Inst. C.E. vol. vi. p. 431.

he said, "no estimate can be formed of our national loss from the over-multiplication of sizes. Take, for instance, the various sizes of steam-engines—stationary, marine, and locomotive. In the case of marine engines, the number of sizes up to 100 HP. will probably not be short of thirty, where ten, perhaps, would be ample. If so, look at the sums expended in patterns, designs, and in the number of tools for their manufacture. Nor is this all; for if there were only ten sizes instead of thirty, there would be three times the number made of each pattern; and, as you know, the very soul of manufacture is repetition. By attention to this the shipowner would be benefited by getting a better engine at a less price. In the case of locomotives and carriages I would urge the subject on the attention of our members the engineers of the great lines of railway—the London and North-Western, the Midland, the Great Northern, for instance. I hope they will permit me to suggest that they should consider and determine not only the fewest possible number of sizes of engines and carriages that will suffice, but also how every single piece may have strictly defined dimensions. This question is also well worthy the attention of our architects and builders. Suppose, for instance, that the principal windows and doors of our houses were made only of three or four different sizes. Then we should have a manufactory start up for making doors, without reference to any particular house or builder. They would be kept in stock, and made with the best machinery and contrivances for that particular branch; consequently, we should have better doors and windows at the least possible cost." From these reflections he was led on to the subject of decimalizing weights and measures. He was in favour of the adoption of the inch as the unit or integer of lineal measure, and thought that "small accurate standards of length of the decimal parts of an inch would be of much service to some trades."

In the same address occur passages which show that Whitworth was keenly alive to the economical and social consequences of mechanical improvement. "The large outlay of capital," he said, "invested in machinery to increase production, makes it impossible to curtail the hours of working machinery as much as could be desired. In some cases, two sets of work-people have been employed in relays, each working eight hours a day; and this system, perhaps, may in time be extended, although it is attended with certain inconveniences. If, however, the relay system could be so improved and organized as to allow more time for the better education of young operatives, none would more cordially rejoice than myself. I believe that mechanics, though a mere material

power in itself, may, if rightly used, become a moral lever, by which, like Archimedes of old, we may seek to raise the world."

At the meeting of the same Institution held in 1857, Whitworth, who was still President, communicated a Paper, "On a Standard Decimal measure of length for mechanical engineering work, &c.," in which the idea thrown out at Glasgow was expanded and developed. He explained his method of measurement by the sense of touch, and his system of gauges. The gauges gradually obtained a widespread use, and in 1881 were adopted by an Order in Council as Board of Trade standards.

In the beginning of the year 1854 the Board of Ordnance requested Whitworth to design and give an estimate for a complete set of machinery for manufacturing rifle muskets in their contemplated new factory at Enfield. With this request, in the comprehensive form in which it was made, he did not feel himself justified in complying. It was then proposed that he should undertake the construction of the machinery for making the rifle barrel only. Before giving an answer he stated that he wished to visit the establishments of the principal gunmakers, and obtain from them all the information he could. He found great differences of opinion among the gunmakers, and the information he received was so contradictory that he was unable to come to any satisfactory conclusion. He subsequently offered to make a series of experiments in order to ascertain on what principles rifle barrels and their projectiles ought to be constructed, and to supply a single set of machinery for their manufacture, provided a gallery for shooting was erected under his direction, where he might make the necessary experiments and obtain facts which would enable him to form a correct judgment. After some delays the Government acceded to Mr. Whitworth's suggestion, and the gallery was built, and finally completed in March, 1855. Early in 1857 Mr. Whitworth was able to report the conclusion of his experiments, and to offer for trial the rifle barrel which he had constructed upon the principles which in the course of his investigation he had established. The official trial of the Whitworth rifle, and its comparison with the Enfield took place in April, 1857, and *The Times* Report (April 23, 1857) stated that "in accuracy of fire, in penetration, and in range, the Whitworth excels the Enfield to a degree which hardly leaves room for comparison."

Whitworth began by rejecting the clumsy systems of rifling previously in vogue, and at once introduced in his experimental barrels a system that he considered mechanically perfect. The

ordinary methods of grooving caused the whole of the work of guiding the bullet to fall upon the grooves of the barrel, and the projections of the bullet. Whitworth, by using a barrel of which each side was a straight line, distributed the guiding power over the whole circumference. A section of his barrel is a hexagon with the angles gently rounded. The hexagon turns as it passes along the barrel, but at every point of the bullet's course to the muzzle it must lie evenly in the grasp of all the sides. The bullet was cast to fit the hexagonal barrel, so as to avoid the distortion of shape that results from expanding a soft bullet into grooves. This system, in which the bore is a rotating polygon, was applicable to barrels of all sizes, from a lady's rifle to a 100-ton gun. Whitworth always asserted that no other method gives the same certainty of producing the effect desired—that is, the regular rotation of the projectile on its axis—and that no other form of barrel can be manufactured with the same accuracy.

Using this system of rifling, Whitworth made a barrel having the same degree of twist as the Enfield rifle then in use—viz., one revolution in 78 inches. The barrel was 30 inches long. "Upon this barrel," he wrote,¹ "the utmost care and attention were bestowed, and it was made as perfect as possible, for I was anxious to test its utmost capabilities. The results, however, were altogether unsatisfactory. The obvious advantages of using long projectiles led me to make very many experiments with them. I at first tried them with rifles having a slow turn, and found that whenever their length much exceeded that of the ordinary-sized conical bullet they invariably turned over in their flight. I endeavoured to remedy this defect by using metals and combinations of metals of different densities, so as to place the centre of gravity in every position that was likely to give more steadiness to the flight. But no change of shape, or combinations of metals, or alteration of the position of the centre of gravity enabled me to use a very long projectile—they all turned over on leaving the barrel, as was made apparent by the marks left by them on passing through paper screens placed near the muzzle. Having exhausted all my resources in prolonged but ineffectual endeavours to use the rifle with the 78-in. turn for long projectiles, I resolved to try the effect of increased rotation by employing a quicker turn. With the view of ascertaining what loss of elevation there might be in consequence, I made a barrel 39 inches long, with what I considered at the time an unusually quick turn of one in 10 in., which gave nearly

¹ Papers on Mechanical Subjects. London, 1882. Part ii. p. 29.

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four turns for the barrel, instead of the half turn previously adopted. On trying the barrel with four turns in comparison with the military rifle having half a turn, I found to my great satisfaction, that it gave an equal elevation. This and subsequent experiments, made with barrels rifled with still quicker turns, prove beyond all doubt that the requisite amount of rotation might be given to the various projectiles without any sacrifice of elevation. . . . I also found, as I expected, that I had no difficulty in firing projectiles of any desirable length without their having a tendency to turn over." He tried barrels with one turn in 20 inches, one turn in 10 inches, one turn in 5 inches, and one turn in 1 inch. In this way he exhausted the subject, and proved that increased rotation neither diminished the range nor heightened the trajectory.

Having thus discovered the means of firing a bullet of any length so as to keep its axis during its flight in the true direction, the next point to settle was what length of bullet gave the best range. The final result was in favour of a bullet of from 3 to $3\frac{1}{2}$ calibres in length. The essential factor thus obtained, the proportion between the length of the bullet and its diameter was, according to Whitworth, the basis of all gun construction. Upon this basis, at any rate, he constructed his rifle. He had been asked by Lord Hardinge to make his barrel to fire a bullet weighing 530 grains, the weight of the Enfield bullet. Given the shape of the bullet and its weight, its diameter is a matter of calculation. Whitworth having decided on a length of three diameters, and the weight being given by Lord Hardinge, the calibre of the rifle was thus fixed. It was 0.45 inch, considerably smaller than the Enfield, which was 0.577 inch. Hence the Whitworth rifle was known as the "small bore." The rifle barrel asked for by the Government had thus been made.

It was repeatedly tried, both by Government Committees and at Wimbledon, and its advocates consider that its superiority was established beyond question. But on being referred to a Committee, this body, in 1859, reported that "the bore of the Whitworth rifle was too small for use as a military weapon." Compare with this the report of another Committee of Officers made in 1862, "that the makers of every small-bore rifle, having any pretensions to special accuracy, have copied to the letter the three main elements of success adopted by Mr. Whitworth, viz., diameter of bore, degree of spiral, and large proportions of rifling surface."¹

¹ "Miscellaneous Papers on Mechanical Subjects." London, 1873, p. 24.

In 1869 a Special Committee reported to the War Office that the calibre of a breech-loading rifle should be 0·45 inch, as appearing to be the most suitable for a military arm. This conclusion is directly contrary to that arrived at in 1859, but coincides exactly with what Whitworth recommended in 1857.

In 1864 a Committee of Officers recommended that breech-loading arms should be adopted for the British service, but Mr. Whitworth was not asked to submit a breech-loading rifle. After a series of committees and trials, the Martini-Henry rifle was adopted in 1871. The Martini-Henry is a combination of the Martini breech mechanism with the Henry barrel, in which some of the principles demonstrated by Whitworth in 1857, viz., the long bullet and quick twist, were adopted. The 0·45 inch bore, which Whitworth had proved to be right for the 530-grain bullet, was retained, but the weight of the bullet was reduced by the Committee to 480 grains. The shooting of the Martini-Henry, therefore, never equalled that of the Whitworth muzzle-loading rifle of 1857 with the 530-grain bullet, for which it was designed.

If a lighter bullet was to be introduced, the proportions of the rifle needed to be modified to suit the altered conditions. Whitworth therefore made a breech-loading rifle to fire the reduced weight of bullet (480 grains) and the same charge of powder (85 grains) as the Government Martini-Henry. For the lighter bullet he reduced the bore from 0·45 inch to 0·4 inch, and increased the rifle twist from one turn in 20 inches to one turn in 15 inches. The polygonal bore of this rifle has twelve sides instead of six, as the twelve-sided form better suits the rifled cartridge designed for it. This rifle, the last made by Whitworth, is probably the most accurate weapon at present in existence.

His experiments, undertaken with a view to the construction of a rifle, led Whitworth to attempt the construction of guns. He had perfect confidence in the truth of the principles which he had ascertained by experiment, and in the soundness of his own method of rifling. Accordingly, his gun differed from his rifle only in size and in such respects as are the necessary consequences of a difference in size. The ballistic performance of the gun, like that of the rifle, surpassed all that had been previously recorded. Neither the one nor the other, however, found favour with the military advisers of the Government. A Special Committee was appointed to report on the Whitworth and Armstrong guns, and after a long series of trials, in 1864 and 1865, presented a voluminous Report. Whitworth's friends consider that in these trials the Whitworth gun proved its superiority in range, penetration,

accuracy, and endurance. But the gun was not adopted by the Government.

It was after the termination of this contest that Whitworth made the greatest of his later discoveries. Experience had taught him that hard steel guns were unsafe, and that the safeguard consisted in employing ductile steel. A gun of hard steel, in case of unsoundness, would break up with terrific results, whereas a gun of ductile steel would bulge and tear under the action of pressure, but would not fly into pieces. When ductile steel, however, is cast into an ingot, it is found in practice that nearly the whole length of the ingot will be subject to honeycomb or air-cells, and will be unsound. Whitworth discovered that the difficulty of obtaining a large and sound casting of ductile steel might be successfully overcome by applying extreme pressure to the fluid metal. A further guarantee of soundness consists in the substitution which he effected of the hydraulic press for the steam-hammer in the subsequent process of forging. Upon this subject may be quoted an impartial authority, the report of the Gun Foundry Board, appointed in 1883 by the Government of the United States.¹ "The Board was allowed the privilege of carrying on its investigations within the works, where, under orders from Sir Joseph, his representatives exhibited, with explanations, the operations carried on in this unique establishment. It may be distinctly asserted that the experiences enjoyed by the Board during its visit amounted to a revelation. . . . In speaking of the Whitworth establishment at Manchester as unique, and of the process of manufacture at that place as a revelation, reference is specially made to the operation of forging. . . . The system of forging consists in compressing the liquid metal in the mould immediately after casting, and in substituting a hydraulic press for the hammer in the subsequent forging of the metal."

The two processes are thus described by the Gun Foundry Board:—"The flask is made of steel, and is built up of sections united by broad flanges bolted together in such numbers as to accommodate the length of the ingot to be cast. All moulds are cylindrical in form. The interior of the flask is lined with square rods of wrought iron, longitudinally arranged, which form, when in place, a complete cylindrical interior surface. Where the square edges of these rods meet they are cut away, both on the inside and on the outside, and, at intervals of 2 inches, small

¹ Report of the Gun Foundry Board. October 16, 1884. 8vo. Washington, 1885, p. 14.

holes are drilled through between the rods, forming a channel-way from the interior to the exterior for the passage of gas and flame. The interior is then lined with moulding composition. The flange at the bottom of the flask, as well as that at the top, is perforated with small holes, which act as a continuation to the perforations between the segments of the lining for the escape of gas. The casting is made directly into the mould from the top. On the completion of the casting, the mould is moved (by means of a railway at the bottom of the casting-pit, which is a deep trench running parallel to the position of the furnaces) to a position under the movable head of the press, which is allowed to descend until the tup is in contact with the metal in the mould, and in this position it is locked; a shower of metal is induced, which ceases almost as soon as commenced, by the complete closing of the mould. The first impress felt by the metal is due to the weight of the head of the press alone. This pressure is gradually increased from below by hydraulic action, applied by four rams upon the table on which the flask rests, until the pressure exerted amounts to 6 tons per square inch. The interval from the commencement of the pressure until the maximum is reached varies with the size of the ingot, being for a 45-ton ingot as much as 35 minutes. During this time the flow of gas and flame from the apertures in the flanges of the flask, at top and at bottom, are (*sic*) continuous and violent, exhibiting the practical effect of the compression. This pressure is applied by the direct action of steam and pumping engines, and is indicated by a dial. At the end of this time the pump is taken off, and a uniform pressure of about 1,500 lbs. per square inch is established by attaching an accumulator to the press, and allowed to remain until the metal is sufficiently cooled to insure no further contraction in the mould. The contraction in length in the mould during the action of the pump, while the maximum pressure is being reached and sustained, amounts to one-eighth of the length of the ingot. After this effect has been produced, there is no further advantage derived from the pressure in the way of eliminating impurities, but the contraction, in cooling, still goes on, and the pressure by the accumulator is considered necessary in order to follow up the metal as it contracts, for the purpose of preventing cracks being inaugurated at the end, and on the exterior of the ingot, by the adhesion of particles of the metal to the sides of the mould. When cooled and reheated, the ingot is brought under the influence of the forging-press. This press is hydraulic, with a moving head having the main hydraulic cylinder fixed in it, and

it is provided with an arrangement of mechanism for raising and lowering the moving head of the press, and for locking the same in any desired position. The press has four hollow pillars screwed part of their length, which are attached to the base of the press by nuts. On the top of the pillars is fixed a cast-iron head or table, supporting two hydraulic lifting cylinders, the rams of which are fitted with cross-heads carrying four suspension bars. These bars pass through the moving head, and are connected at the lower ends by cross bars, which are fastened to the pressing ram. The moving head works between the base and the top or fixed head of the press, and is raised or lowered by the admission or exit of water from the under side of the rams of the lifting cylinders. The moving head can be firmly and rapidly locked at any height from the base which may suit the work to be operated upon. The moving head, as already mentioned, carries a forging or compressing cylinder, which forces a ram down upon the work. By attaching the compressing cylinder to, and making it part of, the moving head, a short stroke can be employed when forging objects which may vary in size from a few inches to several feet in diameter."

The soundness of steel produced by these processes has been subjected to very severe tests. In October, 1872, $1\frac{1}{2}$ lbs. of powder were exploded in a cylinder made of Whitworth fluid-compressed steel, with no other escape for the gas generated than a vent $\frac{1}{16}$ inch in diameter. The cylinder was accurately measured, both externally and internally, before and after the explosion, which caused no alteration in any of its dimensions. The vent, however, had been enlarged in diameter from $\frac{1}{16}$ inch to $\frac{1}{8}$ inch.

The name of Whitworth is inseparably connected with the progress of technical education in England, which at no time received a stronger impulse than from the foundation of the scholarships offered as a permanent national endowment in the following letter:—

"28, Pall Mall, Manchester, 18th March, 1868.

"Sir,—I desire to promote the engineering and mechanical industry of this country by founding thirty scholarships of the annual value of £100 each, to be applied for the further instruction of young men, natives of the United Kingdom, selected by open competition for their intelligence and proficiency in the theory and practice of mechanics and its cognate sciences.

"I propose that these scholarships should be tenable on conditions to be defined by a deed of trust regulating the administration of the endowment fund during my life, and that thereafter the management of this fund, subject to the conditions

specified therein, should vest in the Lord President of the Council or other Minister of public instruction for the time being.

"I venture to make this communication to you in the hope that means may be found for bringing science and industry into closer relation with each other than at present obtains in this country.—I am, &c.,

JOSEPH WHITWORTH.

"To the Right Hon. B. Disraeli, M.P."

The scheme of endowment here set forth was carried out, and the founder, up to the close of his life, continued to take a deep interest in its management. Ten years later he wrote to the Secretary of the Science and Art Department, suggesting considerable alterations in the conditions of the tenure of the scholarships, and offering to defray any additional expenses which might be involved in the change.

The record of Sir Joseph Whitworth's public services would not be complete without a reference to his endeavours to reach a just solution of the problem involved in the relations between capitalist and workman. Speaking on this subject in 1877,¹ he said:—"The relations between foremen engineers and employers have lately become of a much more intimate character, particularly in concerns that have availed themselves of the Limited Liability Act. The foremen engineers have themselves become employers. Three years since, on the 31st of this month, I converted my business into that of a company under the Limited Liability Act, but not in the usual sense where the public are asked to take shares. In my company, myself, the foremen, and others in the concern, twenty-three in number, hold 92 per cent. of the shares, and have the practical control, while the remaining 8 per cent. of shares are held by others. . . . There was no goodwill to be charged for, and the plant was taken at a very low valuation. The shares of £25 were offered, as many as could be taken, to the foremen, draughtsmen, clerks, and workmen. The foremen, besides their salary, receive a percentage upon all that is earned above 5 per cent. For the workman who has not the means to buy shares, arrangements have been made that will, I think, solve some of the difficulties between capital and labour. When the workman who intends to save receives his wages, he deposits with the clerk appointed what he thinks fit. This money is employed in the concern as capital, and whatever dividend is paid to the shareholders, the workman is paid for his deposits in the shape of interest on them. It has been said that these terms are more favourable to the workmen than to the shareholders; but the

¹ The Foreman-Engineer and Draughtsman. Vol. ii. New Series.

shareholder provides only capital, and as the workman devotes both his labour and capital, the terms ought to be more favourable. If the workman, from sickness or other cause, wants to withdraw what he has deposited, he can, by giving three days' notice, receive one-fourth; six days' notice a half, and twelve days' notice the whole of what stands to his credit. When a workman leaves he must withdraw his deposit; and if he holds shares he must sell them to the company at the price he paid for them."

Whitworth's great mechanical and scientific activity, and his unbounded liberality in the foundation of the Whitworth Scholarships, were not without some public recognition. In 1857 he was elected a Fellow of the Royal Society, and was made LL.D. (Dublin) and D.C.L. (Oxford). In 1867 he received at the Paris Exhibition one of the five great prizes allotted to England. In 1868 he was appointed by Napoleon III. to the Legion of Honour. In 1869 he was created a baronet.

Sir Joseph Whitworth's first wife died in 1870, and in 1871 he married Mary Louisa, widow of Mr. Alfred Orrell. For about a quarter of a century Sir Joseph lived at The Firs, Fallowfield, where the well-known shooting gallery still recalls him to the neighbours. His later years were spent at Standcliffe, near Matlock, in the county of his boyhood and early manhood.

He was a great gardener, and used to spend a considerable part of the summer in superintending the transformation of a series of unshapely quarries into one of the most wonderful parks in England. When his advancing age made it difficult to bear the trying climate of an English winter, he formed the habit of wintering in the Riviera. But he was not fond of going abroad, and attempted to establish a Riviera climate for himself by constructing a large conservatory at one end of his house. With the aid of the promenade thus provided, he was able to remain at home during the winter of 1885-6. The following winter, however, he spent at Monte Carlo, where he died on the 22nd of January, 1887.

At the meeting of Council on the 25th of January, reference was made to his death in the following terms, a copy of the minute being ordered to be sent to Lady Whitworth:—

"The death of Sir Joseph Whitworth, Bart., F.R.S., having been reported, it was moved by Sir John Coode, Vice-President, seconded by Mr. Berkley, Vice-President, and

"Resolved, that the Council of the Institution of Civil Engineers desire to offer to Lady Whitworth their sincere sympathy and condolence in the bereavement she has

sustained by the death of her husband, Sir Joseph Whitworth, Bart., F.R.S., Member of Council; and to place on record their high appreciation of the distinguished services rendered by their late colleague during many years in promoting the advancement of the practice and teaching of mechanical science—the primary object of the Institution.”

It remains only to be added that Whitworth joined the Institution as an Associate on the 23rd of February, 1841, his proposer and seconder then certifying that he was worthy of the distinction “because of the eminence he has attained in the construction of tools and machinery”; that he was transferred to the class of Members on the 11th of January, 1848, when he had been for fourteen years in business on his own account, and had acquired distinction “in the construction and adaptation of machinery,” one of the functions of the Civil Engineer as defined in the Charter; and that he was elected a Member of Council at the Annual General Meeting on the 18th of December, 1855—a position he retained till his death, with the exception of six years, 1864–70.

He bequeathed to the Institution eighty fully paid-up shares of £25 each in the Company called “Sir Joseph Whitworth and Company, Limited,” shares which under the special circumstances the Council were advised they could accept, and which have been duly registered in the name of “THE INSTITUTION OF CIVIL ENGINEERS.”

Sir Joseph Whitworth was a man of simple and healthy tastes. Apart from his mechanical work and his garden, he found amusement in his farm and in his horses and cattle, having been in his early days a great rider. He was also a man of strong unbending will, and his unfortunate treatment by the Ordnance Department was perhaps in part due to his inflexible determination. He would not modify a model which he knew to be right out of deference to committees, who, he considered, were incomparably his inferiors in technical knowledge, and who, being officials, were liable to take offence at the plain speaking of one who regarded official and infallible as far from synonymous. His tastes were definite, and he knew well the boundaries—which, however, were by no means narrow—of his intellectual interests. But especially to those who shared his mechanical tastes he was a delightful companion, clear and direct in all his expressions, and revealing, even in the smallest matters, the characteristic of genius—an infinite capacity of taking pains.

The story of Sir Joseph Whitworth's inventions, which has here been briefly told, is an illustration of the truth that the secret of progress lies in method, in the rational adaptation of means to ends. In whatever branch of activity men are content to work at random, neglecting to ascertain the necessary conditions of the problem, or the natural laws that govern the matter of their labours, advancement is seeming rather than real, and lives are thrown away in needless toil. But an examination of the nature of the problem, and an analysis of the difficulties it presents, reveal principles to which effort must conform, and open a way along which every step is a step in advance. Whitworth's early inventions form a series of far-reaching advances in mechanical construction, resulting from the application of a sound method to a few apparently simple problems. The history of the construction of the Whitworth rifle throws additional light upon the value of method. It shows how in a special branch of applied mechanics the investigation and establishment of principles furnished the constructor with an infallible guide, and enabled him to produce results which, after a lapse of nearly thirty years, appear to be final. Sir Joseph Whitworth's treatment of his workpeople, and his munificent foundation of the scholarships which bear his name, are, like his discoveries, the outcome of an effort to extend the influence of reason into every department of action. The world has record of very few lives that have contributed more largely than Whitworth's towards what he conceived to be the great task of humanity—to establish the supremacy of intelligence over the material universe. The great benefactors of mankind, however, have seldom been granted that happiness which might have come from the due appreciation of their work by their contemporaries. Sir Joseph Whitworth was no exception to this rule. His later years were embittered by the idea that injustice had been done him by the British Government, at whose request he had devoted many of his best years to the advancement of rifle and gun construction. He lived long enough, however, to see his rivals adopting one of his most valuable later inventions—his method of casting and forging steel—and he had his consolation in the consciousness that his work was done, not for an age, but for all time.

The portrait which forms a frontispiece to this volume has been engraved, by special permission, from a photograph taken by Messrs. Elliott and Fry, in July 1884.

CHARLES HENRY WARING was born at Plas-y-velin, the residence of his father, Mr. Elijah Waring, near Neath, Glamorganshire, on the 12th of December, 1818. In 1832 he became a pupil of the late Mr. Joseph Tregelles Price, of the Neath Abbey Ironworks and Collieries, and went through the usual educational routine of a mechanical engineer from the pattern shop to the drawing-office. He also learnt surveying, and for some time carried on the plans of the Neath Abbey Coal Company's Collieries; and in 1835 he was severely burnt in an explosion of gas occurring while he was measuring a part of one of the collieries which had not been worked for some weeks. He attended generally to the conduct of the mines, the measurement of the work, and to the accounts both of the ironworks and the collieries; and to the construction of steam engines, machinery, and iron ships, becoming thus acquainted with the mechanical, mining, and commercial branches of the businesses. He was a managing partner of the Neath Abbey Engine-factory and Iron Shipbuilding works from 1845 to 1851, when he sold his interest in them; and of the Abernant Iron Company's Iron Smelting Works in the Vale of Neath, from 1845 to 1868, when they were given up. From 1854 to 1874 he was a managing partner of the Neath Abbey Coal Company's Collieries at Neath Abbey and the Vale of Neath, in the conduct and management of which he was engaged from 1834. In addition to these works, he reported and advised on other collieries and coal properties and made valuations of collieries, ironworks, and mines. In the Exhibition of 1851 he had some coal-cutting machines; but at that time he could get no one, except the late Mr. Charles May, M. Inst. C.E., to believe in the possibility of using compressed air for working machines for this purpose, so his patents were allowed to expire. In the Exhibition of 1862 he had a patent safety-lamp, which was honourably mentioned. By simple mechanical means the collier was prevented from opening it without extinguishing the light, and it was self-locking and required no key. About the year 1874 he retired from active business, and spent the remainder of his life principally in literary pursuits. He was a well-known contributor to some of the lighter journals and magazines of the day. In this connection it is related that in one case he so closely imitated the style of Carlyle's *Sartor Resartus* as to deceive at least one American editor, who republished the essay as from the pen of the Chelsea Philosopher himself. Mr. Waring was elected an Associate on the 3rd of December, 1850, and was transferred to Member on the 7th of May, 1871. He died, after a long and painful illness, on the 9th of September, 1887.

GEORGE WILSON, the Chairman and Managing Director of Messrs. Charles Cammell and Co., Limited, Sheffield, was born in 1829. He was the second son of Mr. George Wilson, of Haugh Mill, Fifehire, who was engaged in the flax-spinning business in partnership with Mr. John Fergus, M.P. for his county.

Mr. Wilson's connection with Sheffield began when he was but nine years of age, at which time he was sent by his father to the Collegiate School of that town. He subsequently finished his education at Edinburgh University, where he distinguished himself more particularly in chemistry, mathematics, and modern sciences. His father was impressed even at that time with the great development which he foresaw was awaiting the iron and steel industries of Sheffield, and consequently procured his son's introduction into the firm of Messrs. Johnson and Cammell, the original founders of the Cyclops Works. George Wilson soon gained the confidence of his employers by giving evidence of great capacity for undertaking duties and responsibilities of more than ordinary importance. An early and signal proof of this ability for business was the successful manner in which he fulfilled more than one mission to America, with which he was entrusted by his employers. On his return to England he was promoted to a high position in the works, and on the death of Mr. Johnson he became Mr. Cammell's partner and responsible manager. In the year 1864 the firm was converted into a Limited Company, under the title which it still bears, and Mr. Wilson was unanimously elected Managing Director, under the Chairmanship of Mr. Cammell. During the next fifteen years his frequent visits undertaken in the interests of the Company to nearly every capital on the continent, as well as to Egypt, gained him a European reputation in governmental as well as manufacturing circles. Upon the death of Mr. Cammell in 1879, he was immediately elected Chairman of the Company. It was during this period that he assisted his brother, Alexander Wilson, in the development of his invention of combining steel and iron in the manufacture of armour-plates, which was afterwards perfected, and is now well known throughout the civilized world as the Wilson Compound system. Previous to 1882 he and his brother, at Dronfield Steelworks, initiated the bold course of removing the export steel-rail trade to the sea coast—a step which was abundantly justified by the course of events. This action may be said to have crowned the advance which has been attained by the Company under the bold but calculating enterprise of its late chairman. From their small beginning in 1842, the works have now come to include the different establishments known as

the Cyclops Steel and Ironworks, Sheffield; the Yorkshire Steelworks at Penistone; the Grimesthorpe Ordnance Tire and Spring Works, Sheffield; the Derwent Steel and Ironworks at Workington; the Oaks Collieries near Barnsley, and the Parkhouse and other iron mines near Whitehaven. These constitute the different departments of an undertaking whose paid-up capital is one and a-half million sterling, and under whom ten thousand hands find employment.

Occupied though he was with these heavy responsibilities, Mr. Wilson was nevertheless on all occasions ready to place his leisure and ability at the service of his fellow-countrymen. In the year 1875, as Master Cutler of Sheffield, he had the honour of entertaining the Prince and Princess of Wales upon the occasion of their visit to the town. He was a Justice of the Peace for the West Riding of Yorkshire.

Mr. Wilson died on the 1st of December, 1885, in his fifty-seventh year. His character was a combination of qualities rarely to be met with in the same man. He was of rare determination of purpose, but at the same time of such unfailing courtesy, that all with whom he was brought into contact were ready and proud to do him service. Though weighted with business of momentous importance, he would receive small and great with the same unruffled composure, and in the same tone of buoyancy which characterized the leisure moments of his unclouded domestic life. His career forms a conspicuous illustration of the secret of real greatness, that they who would be successful masters of others must have first learned to be masters of themselves.

Mr. Wilson was elected an Associate of the Institution on the 7th of March, 1865, and was transferred to the Class of Member on the 25th of March, 1879.

ANTHONY GRANT HOBSON was the eldest son of the late Captain A. P. Hobson. He was born in the West Indies on the 16th of October, 1861, and was educated at Christ's Hospital, which he left at the age of fifteen. He immediately proceeded to Portugal, where he was employed for a year on the Minho District Railway under Mr. John Dixon. He was then articled for three years to the late Mr. W. F. Batho, M. Inst. C.E. After the termination of his pupillage in July 1881, he was for some months engaged in Lancashire to inspect the construction of locomotives for the Barbados Railway Company. When these

were completed he entered the office of the Great Southern and Western Railway of Ireland, at Inchicore. In 1883, Mr. Hobson obtained an appointment in the service of Jerez-Algeciras Railway Company, and left for Spain. He was engaged upon the surveys of that line until the suspension of the work in July 1884. Three months afterwards he was appointed to the construction department of the Rio Tinto Company, when he had charge of railway and dam-work; as also the setting out and construction of work for the extraction of copper from poor ore by the wet method, constructing several sets of precipitation-tanks for that purpose. He would no doubt have remained there and made his mark, for he had excellent natural abilities; but the climate did not suit him, and after struggling ineffectually against constant fever, he was obliged to resign his appointment. Returning to England, he apparently quite recovered his health, and very soon was engaged by Mr. J. Whittall, to go to China on the construction of the Taku-Tientsin Railway. He started in July 1887, full of hope and confidence, but when in the tropics, a return of the fever supervened, and he died at Singapore on the 16th of the same month.

Mr. Hobson was only elected an Associate Member on the 1st of March in the year in which he died. He had previously been a Student.

THOMAS BELL LOW was born at Birkenhead in 1855, and upon completion of his education joined his father, Mr. David Low, then engaged as a contractor in that town. Here he laid the foundations of the practical knowledge of details of construction, and by attendance at the School of Art, erected by Mr. John Laird, M.P., acquired the skill in draughtsmanship which afterwards distinguished him. In 1873 the family left England and settled in Otago, New Zealand. Extensive railway and other works were at that time being vigorously carried on in the Colony, and Mr. Low, shortly after arrival, joined the Public Works Department under Mr. W. N. Blair, M. Inst. C.E., then District Engineer, and now Assistant Engineer-in-Chief for the Colony. In 1878 Mr. Low was appointed one of the principal assistants in the Otago District, and also architect for the Middle Island. Amongst the larger buildings designed by him are the Asylum at Sunnyside, near Christchurch, now in course of erection, and the proposed railway passenger station at Dunedin. In the winter of 1885, during the Russian war scare, directions were given to hastily fortify the

chief ports of the Colony. Mr. Low had superintendence of the defences for the port and town of Dunedin, and threw himself with characteristic energy and devotion into work of an unusually arduous nature, involving close personal supervision night and day at widely scattered points, in the depth of an inclement winter. His work won high commendation from both the civil and military engineers, but ruined his health, which never recovered from the severe strain. A trip to Australia did not produce the benefit expected, and he sailed for England in July, 1886, to try the effects of a long sea voyage, but died while in the tropics on the 12th of September. Mr. Low was well versed in, and was devoted to, his professional work, and was held in deservedly high estimation by the ministers and heads of the department to which he had given twelve years of able and faithful service, and to which his early death is a distinct loss. In private life the earnest and sterling qualities of his mind and character had won him universal esteem, and he will be missed in many circles of quiet usefulness.

Mr. Low was elected an Associate Member on the 2nd of February, 1886.

HENRY ROBERT HOWELLS MARTIN, eldest son of Mr. Henry Martin, Engineer to the Middlesex County Asylum at Hanwell, was born in 1852. He was educated at University and King's Colleges, London, and subsequently became an associate of the latter college. In 1869 he began a three years' pupilage with Messrs. George Waller and Co. of Southwark, London, during which time he had had experience in the design and manufacture; of machinery for gas-works, water-works, breweries, drainage, &c.; was then for nine months (1872) in the office of his father at Hanwell, whilst extensive buildings were in progress for brewery, gas-works, sanitary arrangements, warming and ventilating. In 1872 Mr. Martin became assistant to Mr. Robert Morland, manager of the Gloucester Gas-works, engaged in preparing drawings and specifications for new works capable of producing $2\frac{1}{2}$ million cubic feet of gas per diem; he was then for two years occupied in a similar position under Mr. Thornton Andrews, Assoc. Inst. C.E., at the Swansea Gas-works, during which time the works were entirely remodelled. In 1875 he was made Engineer and Manager of the Llanelly Gas-works, and during the time he held that position the works were doubled in extent. In January 1883 he obtained the appointment of Engineer to the Hong Kong and China Gas Company, which position he retained for several years. Mr.

Martin was elected an Associate of the Institution on the 4th of December, 1877, having previously been a Student, and was transferred to Associate Member on the creation of that class a year later. He died at Panama, on the 26th of May, 1887.

WILLIAM MILLAR, son of General Millar, R.A., was born at Woolwich on the 16th October, 1814. At the age of fifteen he became a pupil with Messrs. Maudslay and Field, and remained eight years with that firm.

In 1843 he accepted the post of Superintending-Engineer for the Russian Black Sea fleet and naval ports, to reside at Nicolaieff, which port became the chief seat of his long labours, with the exception of the period of the Crimean War, when he was sent to Moscow. Mr. Millar occupied this post twenty-five years, and was highly esteemed by all, from the highest to the lowest. In 1867 he was appointed by the Russian Government to be Chief-Engineer to a large rocket-factory which was then in course of erection. The machinery was all arranged and erected from his plans and under his supervision, and for the remaining twenty years of his life he was chiefly occupied with this work, frequently designing new machinery when he saw his way to making improvements.

He received several gold medals from the Russian Government, and was made a Knight of the Order of St. Stanislaus, receiving Queen Victoria's permission to wear the cross and ribbon of the order. He died at Odessa on the 21st August, 1887, after a long and painful illness, and, according to his frequently expressed desire, he was buried at Nicolaieff, in the tomb which contains the remains of his wife.

Mr. Millar was a man who cared little for the praise of those above him, but did his duty for duty's sake, with a single-mindedness seldom met with. He was elected an Associate of the Institution on the 29th of June, 1841, and though long qualified for Membership, elected to remain in the lower grade until 1878, when, the class being reorganised, he was made an Associate Member.

WEBSTER PAULSON was educated at the Grantham Grammar School, and was afterwards put for four years with Mr. T. Chapel, of the firm of Messrs. Cubitt, Gray's Inn Road, London, to learn

the trade of a builder. In 1861 he was chosen by the late Mr. E. M. Barry, R.A., Assoc. Inst. C.E., as his Clerk of Works for the construction of the new Opera House in Malta, where also he commenced and completed the Anglican Church at Sliema for Mr. M. Hills of the Adelphi. Wishing to remain in Malta, he was in 1867 appointed by the local government as temporary Clerk of Works, and in 1873 Clerk of Works on the fixed establishment in the Land, Revenue, and Public Works Department. On the suppression of this department in 1880, he was transferred, in the same capacity, to that of Public Works, which was constituted a separate establishment. Here he continued to serve, under the Hon. E. M. Galizia, M. Inst. C.E., until his death, which occurred from cholera on the 16th of August, 1887, after an illness of six days.

Besides the direction of several architectural works, Mr. Paulson was engaged in the construction of a shipbuilding yard; in the extension of a large boat-slip in the Grand Harbour; in the construction of a boat-slip in the Valley of Zurineg; of a landing-place and breakwater in St. Paul's Bay; and of several sanitary works in Government buildings. He had also charge for some years of the branch "Roads, Streets, Bridges, Lighthouses, &c." and of the repairs of wharves, besides having a considerable private practice as an architect. He was much respected by all classes of the community for his affable and courteous manners, and performed his duties in a manner most creditable to him, and to the full satisfaction of his superior officers.

Mr. Paulson was elected an Associate on the 30th of May, 1876, and was subsequently transferred to the class of Associate Member.

ROLAND PERRIER was born at Geneva, on the 17th of January 1840, but spent the greater part of his early life in Italy, chiefly in Leghorn and Florence. His professional career commenced in the latter city on the Maria Antonia Railway, by a pupilage under Mr. Barnes. In 1860 he obtained an appointment under Mr. John Watson, M. Inst. C.E., on the Bahia and São Francisco Railway, Brazil, at that time under construction, and was employed in superintending iron girder work, the erection of pumping machinery in one of the tunnels during construction, and afterwards as assistant in the workshops of the company, and the erection of locomotives and fixed plant. On the completion of the railway he was employed under the resident engineer, Mr. T. J.

Thompson, M. Inst. C.E., on the erection of iron jetties and warehouses in the city of Bahia in connection with the same railway, and on their completion in 1870, was appointed district engineer on the maintenance of permanent way, which position he retained until his death.

During the time he occupied this position, the work of maintenance was for several years of a very arduous and exhausting nature, the rains in the winter season frequently causing blocks on the line, especially in the years 1872, 1873, 1875, when nearly eleven miles of line were under water, and necessitating constant duty, and the erection and reconstruction of many culverts and iron girder-bridges, which was ably carried out under his supervision. The hardships undergone during this period, seriously undermined his health, and he was subject to attacks of a disease incident to a tropical climate, and which ultimately resulted in his death at sea, on the 10th of June 1887, whilst invalided home.

During the period of his office, he was several times in charge of the whole line, during the absence of the resident engineer, and he had also, on different occasions, charge of the workshops and locomotives department, positions of trust which he filled with zeal and ability. From 1881 to 1884, he was employed on the maintenance of the line, and in office work and details, for the construction of the Timbo Branch Line. Mr. Perrier was an accomplished linguist, speaking with fluency four different languages; and in his private life, was much esteemed for his amiable and generous disposition, which endeared him to all his personal acquaintance, who much regret his loss, at the comparatively early age of forty-seven.

He was elected an Associate-Member of the Institution on the 5th of April 1881.

OTWAY EDWARD WOODHOUSE was born in London, on the 21st of October, 1855. He was educated at Marlborough College from 1867 to 1872, and afterwards at King's College, London. He then passed three years as a pupil with Messrs. Hunter and English, engineers, of Bow, during which time he chiefly applied himself to the practical part of engineering in their fitting shop. In August, 1877, he entered the service of the Great Eastern Railway Company under Mr. W. Adams, M. Inst. C.E., the locomotive superintendent, and on that gentleman changing to the London and South Western Company, Mr. Woodhouse went

with him, and continued in the service of that Company until the beginning of 1881. In July, 1880, Mr. Woodhouse, in company with Mr. J. C. Peache, of the London and North Western Railway Company's locomotive department at Crewe, went to America and spent six months making a tour of inspection of the engineering and general scientific works of the United States and Canada, returning to England at Christmas, 1880. In 1881 Mr. Woodhouse entered into partnership with Mr. F. L. Rawson, under the title of Woodhouse and Rawson, engineers and electric light contractors. This firm is now well known all over the world, a result largely due to the extremely energetic and able manner in which the business was pushed at its commencement. The death of Mr. Woodhouse is primarily due to overwork; it is supposed that the extremely long hours he devoted to the development of the business of the firm must have had a serious effect upon his health, he being too often found in his office far into the night. At the commencement of 1885, Mr. Woodhouse, on account of his health left England for Cannes, from whence he returned to England rather worse, owing to a fever he had caught whilst there. Although he gradually gained strength he never returned to business, and his death, on the 21st of September, at Brighton, although sudden, was not altogether unexpected. His funeral, five days later at Kensal Green Cemetery, was largely attended by personal friends and employees of the firm, showing the great estimation in which he was held by all who came into communication with him. Mr. Woodhouse, besides being an able engineer, was well known in athletic circles. Until his work took up too much of his time he played regularly in the lawn tennis championship matches at Wimbledon, being second in the "all comers," and winning the silver prize in 1880. In that year also he won the lawn tennis championship cup of America. In addition he had the distinction of being the only lawn tennis player who has ever beaten Mr. W. Renshaw for the championship.

He was elected an Associate Member of the Institution on the 3rd of May, 1881, having previously been a Student.

CAPTAIN JOHN COPLEY ADDISON, R.E., was born on the 19th of August, 1852. He was the elder son of Mr. John Addison M. Inst. C.E.

He was educated at Cheltenham, where he earned distinction, and gained many prizes, leaving that College at the head of the

Military and Civil Department. Immediately afterwards, being second on the list of the successful candidates in the open competitive examination, he entered the Royal Military Academy at Woolwich. On subsequently passing out as the most distinguished Cadet of his year, he received, together with several other prizes, the "Pollock" Gold Medal; it being the last occasion on which this medal was presented personally by the venerable General whose name it bears. His commission in the Royal Engineers was dated the 6th of January 1872. After passing through the usual course of instruction at the School of Military Engineering at Chatham, he sailed for India on the 24th of October 1874; and on arrival was posted to the Bengal Sappers at Roorkee. He joined the Public Works Department, as assistant engineer 2nd grade, on the 20th of January 1876, and was posted to the Central Provinces for employment at the military station of Kamptee. At this station he remained up to the 26th of January 1879, except for a short time from December 1876 to May 1877, when he was attached to the Survey of the Nagpur and Chattis-garh Railway (now the Bengal Nagpur Line).

During his employment at Kamptee he had the supervision and construction of many important military buildings. The executive engineer under whom he was working reported as follows:—"I consider that Lieut. Addison, R.E., during the time he has been attached to the Kanham Division, has always displayed considerable physical energy in the discharge of his duties. I am of opinion, that as regards practical work, he has shown great aptitude and efficiency, and that his management of those under his authority, both departmental subordinates and contractors (with their workmen), has been all that could be desired." From Kamptee he was appointed to officiate as assistant secretary to the Chief Commissioner C.P., and secretary to the chief engineer, in which capacity he worked until September 1879, when he was ordered on field service for the Afghan Campaign 1878-80. On his leaving, the Chief Commissioner submitted the following report to the Government of India:—"Lieut. Addison has shown himself to be a most able and scientific engineer, and is also practically good, and most zealous in his work. The Chief Commissioner also expresses a hope that, on his return from service, he may be re-posted to these Provinces." Lieut. Addison was attached to the Kuram Valley Force, under the late Colonel Holmes, R.E., and did the duty of Adjutant of Royal Engineers; he obtained the Afghan medal for his services. After his return from field service on the 11th of November 1880, he was posted on special duty to the chief

engineer's office of Nagpur, where he was engaged on a project for re-modelling the Sitabuldi Hill Fort. This important work he carried out in a most satisfactory manner.

Lieut. Addison obtained furlough to England for eighteen months in 1883, during which period he was under instruction in Photography, Telegraphy, and Submarine Mining, at the School of Military Engineering at Chatham, and made himself proficient in these subjects.

He attained the rank of captain on the 8th of January 1884. He married while in England, and returning with his wife to India on the 28th of November 1884, he resumed his duties as assistant secretary to Chief Commissioner C.P., and secretary to Chief Engineer P.W.D., and continued in this capacity up to December 1886, when he was transferred to the executive charge of the Saugor Division. On the breaking up of this division in April 1887, Captain Addison was posted to the charge of the Hoshangabad Division.

During most of the thirteen years that he served in India, his duties had been of a very arduous and responsible character. He however rapidly acquired experience, affording a bright prospect for his future career, unhappily brought to a close by his death, which occurred at Hoshangabad on the 22nd of June 1887, from heat apoplexy. He was in his 35th year. He was elected an Associate of the Institution of Civil Engineers on the 5th of March, 1878. Captain Addison was held in high esteem, especially by his superior officers. The late Colonel Mayne, R.E., formerly chief engineer C.P., described him "as a most able young fellow, an honour to his profession, and further a favourite with all that knew him." Colonel Ward, R.E., at present Chief Engineer C.P., says, "His sad death is a great loss to us all, both officially, and in many other ways. He was an excellent officer, and did his work well and thoroughly; in private life his kindness and amiability had endeared him to all his comrades. There is a universal feeling of sadness among all his acquaintances in these Provinces."

A high sense of duty was his guiding principle through life.

HARRY CHUBB was born at Bridgwater, Somersetshire, on the 2nd of October, 1816. His father was the late Mr. Morley Chubb of that town, and his mother a daughter of the Rev. Thomas Alford, rector of Chard and Ashill. Coming to London when still a young man he entered the service of the East and West

India Dock Company, and whilst engaged in the Secretary's Department of that Company he showed himself to be possessed of those qualities of intelligent activity which so strongly marked his after life, and he received on one occasion the thanks of his Directors for special services rendered outside the strict sphere of his official duties.

About the year 1846 the scheme of the North London Railway was proposed with the view chiefly of connecting the docks with the London and North Western Railway system, and Mr. Chubb at once threw all his energies into the work, mastering every detail connected with the application for the Act and the construction of the line. As its Secretary and Manager he may be said to have perfected the system of working frequent trains over a considerable length of railway, for though the Greenwich and Blackwall Railways preceded the North London, they were far shorter and had complete control over their own systems. Assured, however, within a few years that the plan first adopted of running its passenger trains into the city over the Blackwall Railway was cumbrous and insufficient for the growing traffic, Mr. Chubb formed the bold idea of bringing the North London Railway into Broad Street, and was instrumental in securing to the Railway the satisfactory and profitable position which it has ever since held. The extension of the system to Kew was also carried out under his superintendence.

His success in these undertakings and the tact which he showed in connection with the various applications to Parliament arising out of them brought him into prominence, and on the retirement, in the year 1862, of the Secretary of the Imperial Gas Light Company, at a time when that Company was seeking powers for the enlargement of its works, Mr. Chubb was asked to take this position. This request he somewhat reluctantly acceded to. The North London Railway immediately invited him to join the board of the Company, and he continued to be a Director of it until his death. It was about this period that he took part in the negotiations for the guarantee of the North and South Western Junction Railway by two of the large northern railways, and became the Chairman of the guaranteed company. His fondness for mechanical science in every branch led him quickly to master the details of gas manufacture and distribution, and very considerable enlargements of the works were carried out; but his peculiar powers of negotiation were again occupied, first in the arrangements with the Government resulting in the present Act affecting gas companies, and secondly in carrying out the amalgamations

which went to form the present vast undertaking of the Gas Light and Coke Company, of which, when the Imperial Company ceased to exist, he became a Director.

The comparative leisure which followed his severance from the active management of the Gas Company, allowed him to widen his interests in those fields with which he was so familiar, and enabled him to accept a seat on the Board of the Brentford Gas Company, and to act as an Auditor of the Grand Trunk and Great Eastern Railways, besides fulfilling the duties of Auditor to the Railway Clearing House. The only other interest with which he was directly connected apart from that of railways and gas, was life insurance, in which he took an active part. For some years he had held a seat on the Board of the National Life Assurance Society.

The peculiar characteristics which Mr. Chubb manifested in his active career, were a calm, self-reliant and courteous bearing, which rendered intercourse with others easy; a conspicuous simplicity and honesty of purpose, which begot and secured confidence, and a great mastery of details. He was eminently a man to whom difficult and delicate negotiations were confidently entrusted. Mr. Chubb was not an engineer, but, having a strong natural inclination in this direction, his scientific knowledge was considerable, and within the limits available to an unprofessional man, he assisted largely in the application of mechanism to the working of railways and the manufacture of gas.

The qualities which led to a uniform success in the chief works of his life were at the disposal of all those, whether individuals or societies, who had any claim upon him. His even and restful temperament, whilst it kept him free from all hurry and excitement, seemed to allow him time for every thing, and his sympathies were wide. Thus the calls which clergymen made upon him for advice and aid in the management of benevolent funds as well as the affairs of such societies as the Railway Benevolent Society, in which he took a great interest, met with a willing and hearty response, and it is not too much to say that he was regarded with a sincere affection by those with whom he was associated, and not least by the large number of working men who from time to time came under his influence.

Mr. Chubb died at his residence in Brighton on the 25th of October, 1887, and was buried at Kensal Green. He was elected an Associate of the Institution on the 2nd of March, 1869.

HENRY MANGLES DENHAM was born 28th August, 1800. He entered the Navy in April, 1809, as a volunteer, on board the "Daphne," 20, Captain Philip Ripon, on the Guernsey and Jersey station, where he served from April 1810 until May 1814, latterly as midshipman, in the "Vulture," 10, Captains Martin White, George Morris, and Henry Baugh. During the three following years he was borne on the books of the "Queen Charlotte," the "Boyne," and the "Prince," ships-of-the-line, but detached the whole of the time on the survey of the Channel Islands, under his former commander, Captain Martin White; with whom as midshipman and lieutenant (commission dated 26th December, 1822,) of the "Shamrock," 14, he was employed from March 1817 until May 1827 in examining the English and Irish Channels, and the south-west and north-east coasts of Ireland.

In October 1827 Mr. Denham assumed command of the "Linnet," 10, for the purpose of surveying the coast of France; and while nominally attached, between September 1828 and March 1835, to the "St. Vincent," the "Caledonia," and the "San Josef," he conducted a survey of the Bristol Channel, and of the ports of Liverpool and Milford. He was promoted to the rank of Commander on the 20th of March 1835, and was employed from January 1842 until July 1845 in the "Lucifer," and the "Royal Sovereign" yacht, in defining the coasts of Lancashire and Cumberland; was then appointed to the "Avon," s.s., and on 27th September following sailed on a surveying expedition to the coast of Guinea, including the mouth of the Niger. He returned to England on the 17th August, 1846, and was borne on the books of the "William and Mary," Royal yacht, from the end of December following until the summer of 1847. From 1848 to 1851 Captain Denham was employed in conducting government inquiries into accidents at sea. In 1851 strong representations were made to Her Majesty's government respecting the rapidly increasing traffic between the Australian colonies and the western coast of America, and the inadequate state of knowledge of the intervening navigation among the insulated rocks and intricate clusters of islands which extend to the eastward of New Caledonia. As a result of these representations an exploring and surveying expedition left England in 1852 in the "Herald," under the command of Captain Denham. A detailed account of the work of this expedition will be found in the Proceedings of the Royal Geographical Society for 1862. It returned to England in 1861, after nine years' absence, and Captain Denham was thanked in the House of Commons for his great services, besides receiving

the voted thanks of various colonial legislatures and other public bodies. In 1864 he was made a Rear-Admiral, and two years later received the honour of knighthood. He was promoted to Vice-Admiral and Admiral in 1871 and 1877 respectively. He died at an advanced age on the 3rd of July, 1887.

Admiral Sir Henry Denham had long outlived the period of his active employment, entering the navy as he did but four years after the battle of Trafalgar, but his name was prominent in the middle period of the century. So much was his surveying work round the British coast esteemed that he was specially promoted to the rank of commander before he would otherwise have gained the step, "To mark the high sense entertained by my Lords of the advantages accruing to the public from the completion of his survey of the port and harbour of Liverpool and the neighbouring coast." He succeeded in averting the threatened return of the port of Liverpool to the mere capacity of a half-tide harbour, by harrowing a new opening through the Burbo and Jordan Sands, which, on the accession of her Majesty to the throne, was named the "Victoria Channel." In reference to a steam survey made by him in the North Sea, the late Hydrographer of the Admiralty, Sir Francis Beaufort, declared it to be his conviction "that no man could have achieved that great work with more skill;" and in remarking upon the survey of Morecambe Bay, the same eminent authority recorded it as his opinion "that a more complete and masterly work had rarely been sent to the Admiralty office." In allusion to Captain Denham's services in the "Avon," on the coast of Africa, whither he was sent for the express purpose of surveying the Bight of Benin, the Hydrographer thus expressed himself: "In examining the survey made in such a deleterious climate, along such an impracticable coast, and in contact with such a treacherous population, I was prepared to make great allowances for work done under such striking disadvantages; but I find, with equal pleasure and surprise, that the whole has been performed with all the precision and fulness that could have been expected if made under the most favourable circumstances." For this service Captain Denham was promoted to post rank. He was the inventor of "Denham Rowlocks" for rowing boats, and of "Denham's (registered) Jury Tiller" for steering a ship on fire abaft, or, when twisting her rudder, ahead, breaking her tiller in a gale of wind, or receiving the enemy's shot. In 1830 he received the thanks of the Trinity Board; in 1834, he was further presented with the freedom of the borough of Liverpool, and elected a member of the Literary and Philosophical Society at that place; and in 1839 he was chosen a

Fellow of the Royal Society; as likewise in 1841, a Younger Brother of the Trinity Corporation, and a member of the United States National Institution for the Advancement of Science. He received the thanks of the Geological Society, of several committees on Harbours of Refuge, and of the Committee of Lloyd's.

Admiral Sir Henry Denham was elected an Associate of the Institution on the 4th of March, 1851, when in the heyday of his career as a marine surveyor.

MAJOR-GENERAL HENRY HYDE, R.E., was the descendant of one of the oldest families in England, his ancestors having been the owners of Hyde Manor, North Denchworth, Berkshire, in the 12th century, and of the whole of the parish of Denchworth for eight generations. The old family house, now the property of Worcester College, is still standing, and one of the roads leading to it is still called "Hyde Way." He was the son of the Rev. Henry Woodcock Hyde, Curate of St. Giles, Camberwell, where he was born in the year 1824. General Hyde's education commenced at the Collegiate School, Camberwell. He next went to Lewisham Grammar School, at that time conducted by Dr. Prendergast. From Lewisham he went to Mr. Statono's school at Wimbledon, in order to prepare for Addiscombe. He left Addiscombe at the age of twenty, coming out second in the list of engineers for his term. Having spent two years at the depôt of the Royal Engineers, Chatham, he was posted to the corps of Sappers, and ordered to India; but being entitled to two months' leave before his departure, he took the first opportunity available for receiving practical instruction in civil engineering by spending the interval in working on the Trent Valley Railway. It may here be noted that civil engineering was the line in which his tastes and the bent of his mind lay, although discharging military duties when called upon with zeal and ability.

General Hyde's Indian career had in it even more than the usual variety that falls to the lot of officers of the distinguished corps to which he belonged. He commenced it in the iron bridge yard in Calcutta, an establishment then kept up by the Indian Government for the purpose of building iron bridges for the use of the Public Works Department. After a few months' service in the yard he was transferred to the Military Department, though his duties partook more of a civil than of a military character, road-making on the Indian frontier being his principal occupation.

There was, however, enough military element in it to keep him on the alert, for he was attacked and wounded while defending himself in the discharge of his civil duties.

In 1849 he was posted to the army of the Punjab, where he did excellent service, being present, amongst other engagements, at the siege of Mooltan. Soon afterwards he was placed in charge of the Peshawur forts, where he showed remarkable powers of directing and managing men. The wild hill tribes, with whom he carried out extensive works, were so satisfied with his fairness, firmness and friendly treatment, that they willingly worked for him when nothing could be done by other authorities on the Peshawur station. He often interested the writer of this notice with stories of his troubles and his triumphs in the management of these tribemen, and to be successful he had, he said, frequently to "work in defiance of all red tape rules." As showing the peculiar character of these men, he mentioned that it was not unusual for one of them to ask for a few days' leave in order to punish some member of another tribe who had done his people an injury, the punishment being to take his life. This being done, the man would return punctually to work at the expiration of his leave, having regarded the occurrence as one of the most ordinary kind. Hyde was Commanding Engineer under Sir Sydney Cotton in 1854, then was appointed Executive Engineer of the Peshawur division, a charge which included both civil and military engineering works of an important character, all of which he did with great credit to himself; though here, too, he went far in setting aside red tape rules, incurring thereby the serious displeasure of his superintending engineer. In 1858 he was again on military duty in an expedition against the Sitana fanatics. During his employment in connection with this expedition he raised the "Pathan Companies of the Sappers," again showing remarkable power in the organization and management of men. He got the Frontier Medal for his services in this campaign, and here ended his military career.

In 1859 he entered on much more congenial work, when appointed Consulting Engineer in the Indian Railway Department. This appointment, which requires a practical knowledge of railway construction, was at that time frequently filled by officers of the Royal Engineer corps who had no previous training or experience in such work, and some of whom were not well suited to the duties they were called on to perform; the fact being that at that period of Indian Railway enterprise there were few if any opportunities of acquiring the necessary knowledge. In this respect General Hyde

formed no exception to the rule; but his natural strong taste for civil engineering was speedily developed, and he soon mastered all the details connected with the work. The writer has heard several railway engineers declare that he was the best consulting engineer they had ever had work to do with.

In 1860 he was transferred to the appointment of Inspector-General of Public Works Accounts, a post not at all suited to his tastes and requirements, and no one was more sensible than General Hyde himself of the disadvantages to the public services involved in such appointments; but it was only another instance of the various and incongruous duties which had to be undertaken at that time by the Royal Engineers in India.

Soon, however, he returned to his favourite work, having been again appointed Consulting Engineer for Railways to the Government of Bengal, an appointment which he filled with great credit until the year 1861, when he was made Master of the Calcutta Mint. Probably no man was ever better suited for an appointment than General Hyde was for this. Mechanical engineering and metallurgy having been his favourite study all through his career, he soon mastered the whole details of mint work, and having done so he lost no time in carrying out improvements and reforms. The changes which he made in the equipment of the mint during his services there were most extensive,—buildings, machinery and furnaces were all improved, enlarged, or entirely reconstructed, his most prominent and important change for the better being the substitution of Siemens's gas-furnaces for the old-fashioned smelting ones in use when he became Master. His knowledge of every detail of the working was complete and thorough; the writer had frequent opportunities of going over the works with him, and could not then, and cannot now, refrain from expressing admiration of the ability and zeal with which he supervised the whole of the working of this great establishment, and when General Hyde made over charge of it, it is no exaggeration to say that it was second to no mint in Europe.

In addition to the purely mechanical and chemical duties connected with the working of the mint, he took great interest in, and collected a vast store of information on the coins and coinage of India, both native and English, his collection being of great interest in some branches of the subject. He frequently talked of putting his store of knowledge, and the results of his intimate acquaintance with the subject, into print, and it is much to be regretted that his numerous occupations prevented him from carrying out his intention. His collection of books on the subject

of coins, and the prices which they brought at the sale of his library by Messrs. Puttuck and Simpson, showed the great interest which he took in the question, and the attention which he bestowed on it. During his services as Mint-Master at Calcutta he was appointed head Commissioner of Paper-Currency, holding the appointment from 1862 to 1870, and so successfully did he conduct it, that on resigning the office he received the thanks of the Governor-General in Council for his services.

In addition to his purely official duties as Mint-Master, he was frequently called on to report on practical and scientific subjects; being a willing and able worker, Government were never backward in availing themselves of his services; indeed, he might be called referee-general on all questions having a scientific side to them. He was President of the Torpedo Committee for the defence of the River Hooghly, and arrived at some practical conclusions on the subject, but the Government of India could not, or would not, supply funds to carry out the proposals. He was President of the Committee for the Inspection of Steam-Boilers, but resigned in consequence of what he considered useful suggestions being ignored. He conducted an exhaustive series of experiments on Indian coal as adapted for steam purposes. He was President of the Asiatic Society, a member of the Calcutta Municipal Corporation, in which capacity he rendered most valuable aid to the town on many occasions by his sound advice on the numerous questions which were discussed in committee and public meetings connected with the great works of drainage and water-supply (carried out by Messrs. Clark and Smith) which were then in progress, involving an ultimate expenditure of more than one and a half million sterling. He was also Fellow of the University of Calcutta, and member of its senate, and he was one of the British Commissioners to the Paris Exhibition of 1867. The following notice of him by the leading Calcutta daily paper, expresses very fairly some of the traits of his character, and the esteem in which he was held by all the sound thinking members of the community.

“His advice was always against the makeshifts too commonly recommended in India by narrow-minded men, which he regarded as wasteful and extravagant in the extreme. And his loss to the community would be very serious in this matter alone, that he stemmed, in some measure, the tide of vague criticisms with which the ‘idle and irresponsible reviewers,’ too much encouraged by the Financial Department, endeavour to swamp every new proposal, however beneficial, or cramp every scheme, however well worked, which involves any expenditure of money.”

In 1876 he resigned his appointment as Master of the Calcutta Mint to take up the duties of Inspector-General of materials for Indian railways at the India Office, another appointment for which he was eminently qualified. During his tenure of the office he devoted himself to the practical part of the duties with the zeal of one who was at his favourite employment. He was thoroughly acquainted with the whole of the details of the work which he had to control, even to the analyzing and testing of the materials. He took a sound, business-like view of his dealings with contractors, considerate to those whom he considered honest and straightforward, and alive to the practical difficulties which contractors sometimes have in carrying out contracts to the letter—apart from the spirit of an engagement. All straightforward, business-like men thoroughly appreciated him, while with those who wished to be more clever than honest, he was no favourite. He could ill brook the amount of red tape control which the routine of the India Office sometimes imposed upon him; but he had ample opportunities of employing his special qualifications in supervising the practical part of the work committed to his care, always advocating the procuring of the best materials and workmanship, and putting down as far as he could, the issue of anything inferior, or even second class in either workmanship or material. In his death the railway department of the Government in India, and its officers who had to rely on their wants being properly attended to at the India Office, have suffered a real loss, which they will certainly feel when the work falls into less practical and weaker hands. The writer of this notice had the pleasure and the advantage of General Hyde's acquaintance for many years—the years when he had attained to ripe knowledge and great experience, and desires to take this opportunity of bearing testimony to his high qualifications as a mechanical engineer, a man of sound scientific knowledge, a considerate yet firm and determined head of his department, and a valuable, kind, and never-varying friend.

General Hyde was elected an Associate of the Institution on the 3rd December, 1861, and served as an Associate Member of Council in the year 1878.

He died at his residence at Burntwood, Caterham, on the 23rd September, 1887.

WILLIAM HENRY MAXWELL was born on the 1st February 1803, at Dundalk, Ireland, and educated in the Endowed Classical Academy of that town. He then studied mathematics and drawing to qualify him for a draughtsman upon the Ordnance Survey of Ireland under General Colby, R.E. He spent five years in the province of Ulster as first-class draughtsman. He then came to England, and was employed for twenty years under Lieutenant-Colonel Dawson, R.E., upon the survey of copyhold enclosure and tithe commutation, when his health and eyesight failing him, he was obliged to retire from the Government service upon a pension. He was elected an Associate of the Institution on the 7th of March, 1843.

* * The following deaths have occurred, or been made known, since the 25th of August last, in addition to those of whom obituary notices have already appeared:—

Members.

BAYLY, GEORGE HENRY (of Mysore).	COX, SAMUEL FITZHUGH.
BRICKENDEN, JAMES GORDON.	COXON, SAMUEL BAILEY.
BULLMORE, FREDERICK CHARLES, JUN.	WILLIAMS, JOHN.
CARR, MARK WILLIAM.	WRIGHT, ROBERT EDWIN.

Associate Members.

BROWN, THOMAS, R.N.	INNES, EDWARD ARTHUR ROBERT.
DADY, JAMSETJEE NESSERWANJEE.	MEYER, CHRISTIAN HENDRICK.
DOWNES, CHARLES CAMPBELL.	SEWELL, JOHN.
HALL, JOHN GREEN.	WEATHERHEAD, PATRICK LAMBERT.

Associates.

GRIERSON, JAMES.	WARING, CHARLES.
ROUTLEDGE, THOMAS.	WEBSTER, WILLIAM.
SCHNEIDER, HENRY WILLIAM.	

Information respecting the life and works, the career and leading characteristics of any of the above, is solicited, to aid in the preparation of future Obituary Notices.—SEC. INSTR. C.E., February 20, 1888.

SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS
AND PERIODICALS.

On the Constitution of Clays. By H. LE CHATELIER.

(Le Génie Civil, vol. xi. 1887, p. 396.)

The hydrated silicates of alumina (clays, kaolins, &c.), in spite of their importance both from the technical and natural history points of view, are but imperfectly understood as respects their chemical constitution. Generally speaking, they consist of mixtures too complex in character for chemical analysis alone to furnish precise information; but the study of their progressive dehydration by heat seems to afford indications of a physical character that may serve for the discrimination of the component compounds.

If a small quantity of clay is heated rapidly, a retardation in the rise of temperature is observed at the moment of dehydration, and the points at which these retardations occur appear to be characteristic of differences in the several hydrated silicates of alumina, as the effects produced appear to be independent of the conditions of the experiment, and particularly of the velocity of heating. The result is similar to that which has already been determined in lime-burning, and is due to the circumstance that the speed of chemical reaction, as soon as it has attained a suitable value, is enormously augmented for very small increments of temperature. The apparatus used in the experiments was a thermoelectric couple of pure platinum and platinum alloyed with 10 per cent. of rhodium, which had been previously applied for similar researches. The observations were registered by the following photographic method: An induction spark recurring at regular intervals of two seconds gives, after reflection by the mirror of a galvanometer, a series of images on the photographic plate, whose distance apart is an exact measure of the velocity of heating. The soldered joint of the pile was placed in the middle of a small piece of clay bedded in a cone of platinum of 5 millimetres aperture, which was enclosed in a large crucible filled with calcined magnesia, the whole being heated in a Fourquignon furnace. Under the conditions of the experiments, about ten minutes was required to raise the temperature to 1000° Centigrade, corresponding to an average rise of four degrees in two seconds. The pile was graduated by observing the boiling or melting points of the following substances:—

Water, 100 degrees; sulphur, 448 degrees; selenium, 665 degrees; gold, 1,045 degrees.

At the moment of fusion or volatilization, the temperature is stationary, and consequently the images of several successive discharges are superposed, producing a dark band on the plate. In some cases, in addition to the retardation due to dehydration, sudden accelerations were observed, indicating the occurrence of phenomena accompanied by a development of heat.

The result of the investigations made with numerous samples of clays and allied substances from the mineral collection of the Ecole des Mines, in Paris, shows that argillaceous minerals may be classified into five distinct types, each being characterized by a particular temperature of dehydration. These are—

1. *Halloysite*, from Miglos, Ariège.—A first pause very slightly marked, was observed at 150° — 200° ; a second very important one at 770° ; and finally, a very sudden augmentation at 1000° . Similar results were obtained with many sedimentary fire-clays, potters clays, and siliceous bauxite. The chemical composition is $2\text{SiO}_2, \text{Al}_2\text{O}_3, 2\text{H}_2\text{O Aq.}$ One half of the water is driven off at 150° in twenty-four hours, or at 250° in a quarter of an hour, but the remainder only commences to separate at 400° .

2. *Allophane*, S. Antoine, Oise ($\text{SiO}_2, \text{Al}_2\text{O}_3, \text{Aq.}$).—The only well-defined pause is between 150° and 200° ; but the sudden acceleration at 1000° is seen as in the preceding instance.

Other samples from Vizé and Utah, and the Collyrite of the Pyrenees behaved similarly.

3. *Kaolinite* ($2\text{SiO}_2, \text{Al}_2\text{O}_3, 2\text{H}_2\text{O}$).—Crystallized China clay from Red Mountain, Colorado. In this, as well as other kaolins from France and China, the only marked pause is that ending at 770° , and a slight acceleration near 1000° , which varies from one sample to another. The latter is probably due to variable quantities of colloidal clay, whose presence has been determined in kaolin by Mr. Schloesing.

4. *Pyrophyllite*, Beresow, Ural ($4\text{SiO}_2, \text{Al}_2\text{O}_3, \text{H}_2\text{O}$).—A first tolerably decided pause was observed terminating at 770° ; and a second doubtful one at 850° . The pagodite (pagoda-stone) of China, behaved similarly.

5. *Montmorillonite*, Dordogne ($4\text{SiO}_2, \text{Al}_2\text{O}_3, \text{H}_2\text{O Aq.}$).—A first principal pause ends at 200° , a second less marked one at 770° , and a third doubtful one at 950° . Numerous other substances, many of which resemble halloysite, belong to this group, but in no case was any development of heat observed as in No. 1.

Clays may, therefore, according to the Author, be classified according to their pyrogenic decomposition with the above categories, which as a rule, are not found to be much mixed with each other.

To complete the investigation, the behaviour of hydrated silica and alumina when heated was investigated. The former shows a pause between 100° and 200° ; but the result with hydrated alumina varies very considerably according to the method of preparation.

When precipitated from aluminate of soda, it gives two pauses, one below 200° , and the other ending at 360° . When precipitated from aluminic salts, or obtained by the calcination of the nitrate at a low temperature, it gives the same pauses and a sudden rise at 850° . The latter corresponds to the temperature at which calcined alumina becomes insoluble in acids. Lastly, the hydrate obtained from bauxite gives a pause ending at 700° , that is, at the same temperature as in halloysite. From these observations it follows that the presence of hydrated silica cannot be experimentally established in any hydrated silicate of alumina, and on the other hand the first two hydrates of alumina cannot be found in any case, and that of bauxite can only exist in the halloysite group.

Further, it is apparent that the development of heat observed in the baking of clays belonging to the first and second groups is to be attributed to the molecular transformation of the contained alumina, as it is only after the development of this phenomenon that the alumina of clays becomes insoluble in acids. As no free alumina exists in clays in a natural state, its presence is to be attributed to a decomposition of the silicate at the moment of dehydration.

H. B.

Brick Pavement for Streets. By J. H. SARGENT.

(Journal of the Association of Engineering Societies, 1887, p. 329.)

The Author communicates his experience to the Civil Engineers Club of Cleveland, of wood, stone, and brick-pavements for streets. The experience generally of wood pavements has been unfavourable. Some streets were paved on the Nicholson system with poor lumber, made from dead timber, and the work was inferior. The blocks rotted and disappeared in a very few years. A cheap wood pavement consists of cedar poles cut into 8-inch blocks, bedded in good gravel. Madison Street, Toledo, was paved in this manner with red cedar from Tennessee, and has stood for several years without failure or repair. White cedar lasts for ten or twelve years before it rots.

Pavement made of hard-burnt clay bricks has proved successful. The bricks should be burnt hard enough to vitrify the moulding sand on their surfaces, and convert them into pieces of igneous rock. They are thus rendered impervious to air, water, and fire; they are homogeneous, slightly elastic, and more resistant than granite. Their tenacity and resistance to wear are remarkable. It is thought that the fire-clays of the coal measures produce bricks better suited for pavements than the common red clays. But bricks made of common clay have been used in Charlestown, West Virginia, and Bloomington and other towns in Illinois, for upwards of twelve years. Some of these bricks, taken up after ten years of wear, had

een worn down less than a quarter of an inch. A section of brick pavement was laid last year in the tramway track in Cleveland. It does not exhibit wear or deterioration, and makes a smooth, quiet, and dustless street. A perfectly formed and consolidated road-bed made by rolling or pounding, covered by a single course of brick, laid edgewise, grouted with hot asphaltum and sharp sand, "makes a perfect continuous floor on a foundation that cannot escape." But, in the discussion, Mr. H. M. Claflen remonstrates:—"How are you going to say whether firebrick is soft or hard?"

The evidence, voluntarily contributed by local authorities on the behaviour of brick-paved streets, is promising. In Bloomington, Illinois, 1 inch depth of sand is first laid, then a course of bricks laid flat; next a thin layer of sand, then a course of bricks on edge, $\frac{1}{4}$ inch apart, packed with sand. At Wheeling, W. Va., brick pavements exclusively are now laid; those laid three years ago do not show any appreciable wear, and they are not smooth and slippery in winter; they are almost noiseless and are easily cleaned; the drainage is quick and complete. The pavements are laid at a cost of 6s. 8d. per square yard, including all material and labour, and the preparation of a bed to receive the substratum of gravel or sand. The bricks are 9 inches by 3 inches by 5 inches, and they weigh 9 lbs. 10 ozs. each. In Charleston, W. Va., the clay used for paving-bricks is simply a good quality of common building-brick clay, tough, stiff and tenacious. In Champaign, Illinois, brick-pavement after three years' trial does not show any wear. It cost from 6s. 8d. to 7s. 9 $\frac{1}{2}$ d. per square yard. At Steubenville, Ohio, fire-brick pavement has been down three years, and has not cost anything for repair. The cost of paving is from 3s. 6 $\frac{1}{2}$ d. to 4s. 2d. per square yard. The hard-burned red brick stands a pressure of 5 tons; the new Cumberland fire-brick, 80 tons of pressure; the pavement is smooth but horses never slip on it. The Hale Pavement Company, of Staunton, Va., lay a pavement of first, sand, then boards dipped in hot coal-tar, then hard-burned bricks.

The Medina stone pavement is noticed at some length in the Paper, as well as in the discussion.

D. K. C.

Resistance to Crushing of Stone Partially Loaded. By A. FLAMANT.

(Annales des Ponts et Chaussées, vol. xiv., 1887, p. 230.)

In ordinary crushing-experiments, the block to be crushed is supported between two pressure-plates larger than the block itself, so that the pressure is nearly uniformly distributed on the faces. This Paper contains experiments on cubes and cylinders in which, on one or both faces, a pressure-plate is used smaller than the block. The first experiments were on cubes of 4 inches length

of side. The pressure-plate was a square block of from 0·4 to 3·2 inches length of side. Some of the experiments were on blocks of a soft stone; others on blocks of cement. The following Table gives a summary of the principal results:—

CRUSHING-LOAD OF CUBES, 4 inches × 4 inches × 4 inches.

Length of side of Pressure-Plate.	Small Pressure-Plate on top face. Bottom face supported all over.				Small Pressure-Plate on both surfaces.	
	Soft Stone. Load in lbs.		Cement. Load in lbs.		Soft Stone.	Cement.
Inches.	A.	B.	A.	B.		
0·4	2,660	2,960	9,850	9,850	3,060	9,850
0·8	3,120	5,620	23,300	21,200	3,670	16,900
1·2	5,300	7,350	31,000	32,400	4,170	26,600
1·6	8,100	8,100	48,000	44,300	6,800	30,200
2·0	10,600	11,300	58,000	59,700	6,600	33,700
2·4	12,000	11,900	73,000	75,000	10,600	48,000
2·8	13,400	11,900	84,000	83,000	7,500	62,000
3·2	13,500	..	95,000	91,500	13,800	65,000

A. Pressure-plate parallel to sides of cube.

B. Pressure-plate placed diagonally.

The results with a pressure-plate on both sides of the cube smaller than the cube are somewhat irregular, and correspond to conditions not often present in practice. The other results, with a pressure-plate smaller than the cube on one face, and the other side completely supported, are more regular. The pressure at which the cube crushes is nearly proportional to a geometric mean between the side of the cube and the side of the pressure-plate. If R is the crushing-pressure per unit of area of a cube crushed in the ordinary way, with complete support on both faces, and P the crushing load of a cube of length of side A , with a pressure-plate on one side of length a ,

$$P = R A a.$$

There are also some experiments on cylinders.

W. C. U.

Experiments on Abrasion.—By — THOULET.

(Annales des Mines, vol. xi. 1887, p. 199.)

The abrading action of sand carried by the wind, constitutes an important factor of geological phenomena in some parts of the world, and with the object of accurately studying the nature of this action, the Author undertook a series of experiments in which slabs of various materials were subjected to the action of a kind of sand-blast.

The apparatus used consisted of an air-pump driven by hand

in connection with a reservoir from which air was forced under a given pressure through a conical mouthpiece into which sand from a glass vessel was allowed to flow through an india-rubber tube. From the mouthpiece the sand was blown against the slab of material to be operated on, contained in a box, and so fixed as to be adjustable as regards distance from the mouthpiece and inclination. The sand escaped from the box, by tubes passing through one side, into two glass jars from which it could be easily collected. A mercurial gauge was used in connection with the air-reservoir to measure the pressure, which during each experiment was maintained as constant as possible.

The slab exposed to abrasion was carefully weighed before and after the experiment, and also the sand and rubbish collected from the glass jars and bottom of the box, the difference between the weight of the latter and of the former gave that of the sand used.

The observations were directed to ascertaining the influence on the quantity of material abraded of the following factors:—

Quantity of sand used, distance of the slab from the orifice of the sand-blast, dimensions of the sand-grains employed, nature of the latter, pressure of the air, inclination of the slab relatively to the direction of the blast, nature of the abraded slab, and humidity of the same.

The materials tested were glass, iron, copper, lead, tin, quartz, basalt, limestone, granite, phonolite, serpentine, and marble.

The results obtained with quartz, on a polished surface at right angles to the optical axis, were taken as the standard of comparison for other materials, and the Author denotes by coefficient of abrasion of any substance, the ratio of its abrasion to that of quartz under the above conditions.

The experiments were made with air-pressures varying from 8 to 26 centimetres of mercury, and the effects obtained all reduced to those resulting from the action of 25 grams of sand.

The following is a summary of the results observed: The abrasion is directly proportional to the quantity of sand by which it is caused. Stone resists abrasion better when polished than when rough. Up to a certain point, abrasion increases proportionally to the distance which separates the slab used from the orifice of the blast, but after that point is passed the abrasion decreases; the less the pressure, the sooner is this limit attained. Grains rounded by use produce less effect than those which are fresh and sharp. The abrading action increases with the size of the grains of sand used.

Powdered limestone produces no effect on quartzose rock; limestone acting on limestone, or quartz on quartz, cause the same abrasion; the maximum effect results from quartz sand working on limestone. Abrasion is directly proportional to the pressure producing the blast, and is more energetic when the surface on which it acts is vertical to the direction of the blast than when it is inclined; it diminishes very rapidly when the angle is less than 60°.

In the case of crystals, the abrasion like all other physical properties, follows the laws of crystalline symmetry.

For equal hardness rocks composed of small particles resist abrasion better than those of which the elements are coarse and of different characters. The abrasion of rocks is greater when damp than when dry.

G. R. B.

New German Standard Rules for Testing Portland Cement.

(Deutsche Bauzeitung, 1887, p. 400.)

In November 1878 the Prussian Minister of Public Works issued a series of standard rules for testing Portland cement, which were adopted by most of the architectural and engineering associations in Germany, and subsequently served as a basis for standard rules in several adjoining countries. At the instance of the Association of German Cement Manufacturers, these rules have now been altered, and several important modifications introduced. The amended rules were published by the Prussian Minister of Public Works in July 1887, and differ from the rules previously in force as follows :—

The time of setting of a slow-setting cement is now fixed at two hours, instead of half an hour.

In testing for expansion, the cake of cement is allowed to set for twenty-four hours before immersing in water, during which period it is kept moist and in the shade.

The cement must be ground so finely that not more than 10 per cent. residue remains upon a sieve of 900 meshes per square centimetre (5,806 meshes per square inch), and made of wire the thickness of which is one-half the width of the mesh ; 100 grams (0·22 lb.) of the cement is to be used for each test.

The strength is ascertained by tensile and compressive tests ; the cement in both cases being mixed with three times its weight of sand of a definite size of grain.

The breaking-area of the tensile briquettes is 5 square centimetres (0·775 square inch), and the compression-tests are made with cubes of 50 square centimetres (7·75 square inches). Tests with neat cement are to be preferred when Portland cement is being compared with other hydraulic cements. In order to secure uniformity, it is recommended to use similar apparatus to that in use at the Royal Testing Establishment at Charlottenburg, near Berlin.

The minimum tensile strength of a mixture of 1 part by weight of slow-setting cement, mixed with 3 parts by weight of standard sand, after hardening one day in the air and twenty-seven days under water, is 16 kilograms per square centimetre (227·5 lbs. per square inch). The crushing-strength is 160 kilograms per square centimetre (2275·6 lbs. per square inch).

In giving the strength of Portland cement, the time of setting should always be mentioned, the strength of quick-setting cements being lower than that of slow-setting cements. The final test of strength is the crushing-test in twenty-eight days, the twenty-eight day tensile test being used for ascertaining the quality of the cement as delivered. The seven-day test may be used for the latter purpose if the ratio of the seven-day strength to that at twenty-eight days has been previously determined for the cement under examination. This preliminary test may also be carried out with neat cement, in which case the strength of the same cement neat at twenty-eight days must be known. The standard sand is obtained by sifting clean quartz sand first through a sieve of 60 meshes per square centimetre (387 meshes per square inch), made of wire 0.38 millimetre (0.0146 inch) diameter, then through a sieve of 120 meshes per square centimetre (774 meshes per square inch), made of wire 0.32 millimetre (0.0123 inch) diameter. The sand which remains upon the finer sieve is that which is to be used for the tests. For each series of tests ten briquettes at least must be broken, the average of the ten numbers obtained being taken as the strength of the cement. In making each five briquettes for the tensile test, 250 grams (0.55 lb.), of cement is mixed with 750 grams (1.65 lb.) of standard sand, and 100 grams (0.22 lb.) fresh water, the whole mass being well mixed for five minutes. The mortar is beaten into the moulds for one minute with a spatula weighing about 250 grams (0.55 lb.), until water begins to rise. When the surface has been smoothed with a knife, the mould is carefully removed, and the briquette placed in a covered zinc-lined box for twenty-four hours. It is then immersed in water for the remainder of the hardening period. In making these briquettes by machinery, Dr. Böhme's apparatus is used; 180 grams of the mortar is placed in the mould and subjected to one hundred and fifty blows of a hammer weighing two kilograms (4.4 lbs.). In case of dispute, the results obtained by means of the machine are to be considered final.

For the crushing-tests, Dr. Böhme's machine alone is prescribed, the proportion of water and number of blows of the hammer being the same as for the tensile briquettes.

In making the neat tests, 1,000 grams (2.204 lbs.) of the cement is mixed with 200 grams (0.44 lb.) of water; but with very finely-ground or quick-setting cements, the amount of water may be increased.

In giving the results obtained, the proportion of water used must be stated.

All briquettes must be tested immediately they are removed from the water. In breaking the tensile briquettes, the weight must be added at the rate of 100 grams (0.22 lb.) per second.

W. F. R.

On the Constancy of Volume of Hydraulic Cements.

By Prof. L. TETMAJER.

(Schweizerische Bauzeitung, 1887, p. 59.)

The technically most important quality of cements is their constancy of volume. Hydraulic cements may be considered to possess this property, if, when mixed neat without the addition of sand, they permanently retain the form in which they were moulded in the air or under water.

Many cements which are perfectly durable under water have been found to deteriorate in the air. This occurs, according to the Author's experience, with sharp burnt cements, and shows itself in disintegration commencing at the exterior, and gradually increasing, accompanied by the absorption of carbonic acid from the atmosphere. Various examples of this behaviour with an analysis of the cements with which it occurred are cited by the Author; experiments have proved that the phenomenon is not due to the chemical composition of the cement, but is a result of an imperfect preparation of the materials, insufficient homogeneity and mixing of the components and consequent defective decomposition of the silicates in the fire, which cause the formation of products similar in their character to Portland cements, poor in lime and rich in alumina. When cements of this kind are mixed with water, a dissociation of the combinations formed by burning occur, probably accompanied by the formation of unstable hydrosilicates and calcium-aluminates, which part with a portion of their water at relatively low temperatures, disintegrate and may possibly be decomposed by the action of the carbonic acid of the atmosphere.

As a test to guard against defects of this character, the Author recommends that slabs of about 4 inches diameter, and $1\frac{3}{4}$ inch thick, should after setting, be subjected to a temperature of about 120° Centigrade for from three to four hours in a drying-chamber. Cements which stand this test successfully, may be relied upon to resist atmospheric influences.

With respect to cements which change their volume and deteriorate under water, the Author states that this result may be due to the following causes: (a) An excess of constituents, which increase their volume by oxidation and subsequent absorption of water; to these belong the sulphides, more especially sulphide of calcium: (b) Coarse grain, insufficient homogeneity and defective burning. In this case the destructive agent is quicklime, surrounded by a crust of calcium ferrate: (c) Excess of substances requiring slaking, including quicklime, gypsum, and magnesia.

To accelerate the tests for the defects named under (b) and (c), the test-pieces may be placed in steam or boiling-water, instead of cold water as in the normal tests. This treatment, however, is only suitable for Portland cement and slag cements, for other kinds it is too violent.

G. R. B.

The Resistance of Masonry Arches. By A. CREPIN.

(Annales des Ponts et Chaussées, vol. xiii., 1887, p. 689, 4 plates.)

Though many authors have treated of the theory of masonry arches, it has been always assumed that the voussoirs rest against each other without mortar, which, though possibly applicable to ashlar set in poor mortar, does not embrace arches constructed of small materials, with excellent mortar, or monolithic concrete arches; nor do the theories that have hitherto appeared take into account at all the rolling loads, an omission, the defects of which are clearly indicated by the graphic processes followed by the Author. The elaborate treatment of the subject, and the numerous graphic diagrams used for illustrating the methods adopted, preclude more than a brief summary of the heads of the articles being reproduced here. After glancing, in the introduction, at the methods adopted by Mr. Méry, Mr. Durand-Claye, and Mr. Gobert, in determining the curve of pressures, the Author deals in the first chapter with preliminary considerations and principles; he accepts the trapezoidal hypothesis of Bernoulli for the distribution of pressures in any section of a solid; and deeming it erroneous to consider only the normal resultant, he states that when a pressure is oblique to a joint it is applied wholly on the joint, in respect of the molecular strains, as if the pressure was normal to it. The curve of pressures adopted is the curve of the least molecular strains, which is the curve of pressures of equilibrium, for any change of the curve would involve greater strains. To determine this curve, take the joint of the crown and the joint of maximum thrust, which is at the haunches in semicircular arches, and at the springing in segmental arches, and find the position of the curve for which the greatest pressure per unit of surface is a minimum, both at the crown and at the joint of greatest thrust. In the second chapter, the pressures on a joint are determined graphically; the third treats of the equilibrium of the portion of the arch between the crown and the joint of maximum thrust; and the fourth of the joint of maximum thrusts, and of elementary maximum pressures. The curves of pressures for any arch under the action of permanent and of rolling loads are then determined graphically. It is next shown that the method is applicable for a distribution of pressures in accordance with Bernoulli's law. The influence of the filling placed on arches is considered in Chapter 8, and a rolling load distributed over several pair of wheels in Chapter 9. Practical consequences are then discussed, and examples of the construction of diagrams given. Lastly, the method is shown to be applicable to the case of voussoirs not set in mortar, and for determining the influence of sliding and friction; whilst a summary of the results is given in Chapter 13. The method demonstrates that the rolling load subjects the materials of an arch to decidedly greater pressures than the distri-

buted loads; and it enables the maximum pressures, to which an arch may be subjected, to be determined according to the loads it has to bear. Owing to the precision and clearness of the method, as regards the theory of arches, it would be useful in designing them; and various other problems, besides those considered in the article, might be studied by its aid.

L. V. H.

New System of Portable Metallic Bridges for Quick Erection and Removal. By — PICHault.

(Annuaire de l'Association des Ingénieurs sortis de l'Ecole de Liège, 1887, p. 147.)

The Author begins with a reference to the systems of Eiffel, Cottrau, Henri, Marcille, Brochocki and Rocchi, and adjoins a description of his own system designed and patented for the Sclessin Company in Belgium. All these systems aim more or less at the construction of simple girder-bridges out of parts repeating as often as possible in the same bridge, or in the whole system of bridges. The parts are arranged in the usual systems of triangulation. This is attained in—

(1) Eiffel¹ system, by elements of the form of an isosceles triangle, with a base of about 20 feet and a depth of 5 feet, having a vertical in the middle. The bases are made to overlap half-way and form a girder without a bottom flange, which then is added separately. The connections are by bolts.

(2) Cottrau² system, by elements of the form of a quadrangle, about 6 feet by 4 feet, with two diagonals. These are bolted together either with their long or their short sides, and are armed at top and bottom with flat bars according to requirement.

(3) Henri system, by elements of the form of an equilateral triangle, of 3 feet 8 inches side.

(4) Marcille system, by sections of girders, 25 feet to 30 feet long, bolted together end to end to make the main girders of bridges of 100 to 150 feet span.

(5) Brochocki system, by single bars or struts of 13 feet length, fixed together in equilateral triangulation by pins in the manner of American bridges.

(6) Rocchi system, by elements of the form of a parallel trapeze with two diagonals bolted together with their parallel vertical sides so as to make girders with a straight top flange and a polygonal bottom flange.

The Author finds fault with the previous systems in so far as in them the transverse parts of the bridges are not constructed of

¹ Minutes of Proceedings Inst. C.E. vol. xc. p. 482. "Nouveaux Ponts Portatifs économiques, système Eiffel." A. Vincent. Paris, 1884.

² *Ibid.* "Ponti Politetragonali portabili, sistema Alfredo Cottrau." Milan, 1884.

elements similar to those of the main girders; further, as little provision is made for varying the strength of the parts according to the forces acting in them; and finally as the range of span is too limited, namely, about 160 feet. He then describes in detail his own arrangement, to which he has given the name of "Sclessin" system, from the title of the Belgian establishment to which he is engineer, and shows its extensive applicability.

Three identical angle-irons and three identical gusset-plates are used to make the equilateral element. In order to join several elements together four other forms of gussets are required, and to join them transversely one more gusset. For the purpose of varying the strength of the flanges two kinds of flat bars are used, one 3 feet 8 inches long and the other 11 feet 4 inches long, or this length increased by any multiple of 5 feet 8 inches. All the angle-irons and flat bars have bolt-holes of equal diameter and recurring pitch throughout their length, and the gusset-plates are all pierced according to the same pattern. Of these holes only those, of course, are used which are required. The diagonals of the web of the main girders, or of the wind bracing, are thus always of the same section, and it appears that if more strength in them is required, the depth of the girders has to be doubled or trebled, or the number of girders placed side by side has to be increased.

M. A. E.

[Two principles seem to have been followed in the design of the various above-named systems, viz.: *first*, that parts of bridges of given spans and widths should be kept ready for an emergency without making it an absolute requirement that the parts of one bridge should be usable for or interchangeable with those of another bridge, this principle prevailing notably in Eiffel's system; *second*, that a large number of parts of very few kinds should be kept ready and that they should all be interchangeable with regard to bridges of different sizes, this principle being most strictly observed in Pichault's system.

The latter principle would involve the inconvenience necessarily experienced in constructing flanges and diagonals of large girders out of small and comparatively weak elements, while the former principle would not permit the parts intended for a small bridge, and having arrived at the site of a large bridge to be used under the altered circumstances. Engineers, military or other, will have to choose between these two shortcomings.

The Paper does not deal with any system of bridge construction except that of the simple girder.—M. A. E.]

Iron Lifting-Bridge at Königsberg. K. KINZER.

(Zeitschrift des Österreichischen Ingenieur- und Architekten Vereines, 1887, p. 127.)

The two channels of the Pregel at Königsberg are crossed by a number of old wooden bridges with opening spans, which structures are, as they decay sufficiently to render reconstruction advisable, being replaced by iron bridges. The latest of these new structures, on the site of the old Kottell bridge, is constructed on the type of the 75-foot bridge at Rotterdam, with such improvements as have

since been suggested by experience. The central span is made of two lifting or balanced halves, instead of on the swing-type, on account of the loss of quay-space and waterway, and diminished clear headway involved by the latter.

The river is at this point 180 feet wide. The bridge consists of two fixed spans of 39 feet $4\frac{1}{2}$ inches, and the central span of 60 feet 8 inches between bearings, with a clear waterway of 41 feet. The roadway is 23 feet wide throughout, and the footways on each side, which are carried on cantilevers, are 8 feet $2\frac{1}{2}$ inches wide over the fixed spans, and 6 feet $6\frac{1}{2}$ inches wide over the central span, giving total widths between parapets of 39 feet $4\frac{1}{2}$ inches, and 36 feet 1 inch respectively. The gradients on the approaches and side-spans are 1 in 40, and over the central span 1 in 100 from each pier to the centre. The piers and abutments, on pile and concrete foundations, are built of brick in cement, with light yellow pressed brick facing, and starlings, copings and bedstones of Swedish granite. The piers are protected by fenders of wood and iron. In the side spans the two main girders are 26 feet 3 inches centre to centre, with cross girders at 13 feet $9\frac{1}{2}$ inches intervals and longitudinal bearers. An additional cross-girder gives the necessary stiffness to the end of the platform of the fixed span butting over the balanced girder end on each of the river-piers. The two balanced lifting-halves of the central span consist each of two main girders, with cross girders and longitudinal bearers for the road plates. The main girders, which are hung at each side on a steel shaft $8\frac{5}{8}$ inches in diameter on double bearings, are 5 feet 11 inches deep at this bearing point, with parabolic lower flange reducing the depth to 1 foot 7 inches at the centre, and are spaced 22 feet centre to centre. The cross girders are 8 feet $6\frac{1}{2}$ inches, and the longitudinal bearers 3 feet $3\frac{1}{2}$ inches centre to centre. The counterweight is carried by a depressed cantilever 12 feet in length, overlapped by the platform of the fixed span; and when the bridge is open, this counterweight sinks into a recess in the masonry of the pier. In its normal position the girder rests on a bedplate on the face of the pier, 4 feet 3 inches forward beyond the shaft-bearings. The road platform over the central span is formed of steel plates.

The opening span is worked by hydraulic power. The water is drawn from the town main; but in case of any breakdown can be taken direct from the river. To provide also against any contingencies or derangement of machinery the bridge can, if requisite, be opened and closed by hand-gearing. The accumulator and motor are placed in a small building adjoining the bridge. The accumulator, with a maximum load of 74,800 lbs., gives a water-pressure of 632 lbs. per square inch. The 3 HP. Schmidt hydraulic motor has a cylinder 5.9 inches in diameter and 7.88 inches stroke, and makes 70 revolutions per minute, working two coupled pumps. The reserve power is provided by a Körting gas-engine working at 175 revolutions per minute. The pressure-main from the accumulator is $3\frac{3}{16}$ inches diameter; it extends to the centre of each pier, and there divides into two branches, in order

that the pressure on each side may be equal and simultaneous, and avoid any torsion in the shaft. The process of opening the bridge is effected in fifteen seconds, and closing in twenty-five seconds.

The total cost of construction was £18,500.

P. W. B.

Re-construction of the Bridge over the Maas at Venlo.

By LEO BACKHAUS.

(Zeitschrift des Vereines deutscher Ingenieure, 1887, p. 719.)

The special feature in connection with the work of widening this bridge was the necessity of shifting the existing superstructure laterally to the extent of nearly 5 feet without interrupting either the road or railway traffic. The old bridge, crossing the Maas near the town of Venlo, was built for a single line of railway, accommodating the traffic on the Venlo and Nymwegen and the Venlo and Helmond lines. At the same time, by a peculiar provision, the ordinary road traffic was accommodated on the same bridge. The clear space between the girders was 23 feet, and the roadway was formed of timber planking carried close up to the rails on each side, with only a longitudinal baulk to keep the line clear. There was thus on each side of the rails a roadway 6 feet 6 inches wide, and a raised footway only 16 inches wide—the line forming practically the centre of the road, so that the two classes of traffic had to be worked alternately. The railway service comprising forty-six trains, passing between 5.26 A.M. and 11 P.M.—a space of 17 hours and 34 minutes—and requiring 15 minutes clearance of the bridge for the passage of each train, or 11 hours and 40 minutes altogether, the time left for the vehicular and foot traffic between these hours was reduced to 6 hours and 4 minutes. In course of time this allowance was totally inadequate to the requirements of the increasing traffic, especially in the busiest hours of the day. With a view to later widening by the addition of another single-line bridge, the abutments and piers were originally constructed of such width as to allow of this alteration of the superstructure; but the development of international traffic through this frontier point, and its connection with the Rhenish railways on the one side, and England via Flushing on the other, necessitated the provision of a double line of rails simultaneously with the improvement of the roadway. The existing structure not being strong enough to accommodate a double line of railway, it was necessary to provide the new part of the structure for this purpose, and to leave the old bridge for road traffic only; but as the space allowed on the piers was insufficient for this purpose, the only alternative, except widening the piers, was to shift the whole old superstructure nearer to one side of the piers, when there would be sufficient space for the widening. Two essential conditions were laid down for carrying out the work, viz., that

the new superstructure must previously be erected on the piers, in so far advanced a state that it could be opened for traffic within six weeks, and that the railway traffic should not be interfered with. This involved the necessity of carrying out the work within 6 hours 26 minutes, *i.e.*, between the passage of the trains at 11 p.m. and 5.26 a.m. As actually carried out, however, the new bridge was so far advanced that temporary switches were laid in so that trains could pass over this latter, and the work was therefore able to be carried out without apprehension of any contingency of blocking the traffic.

The bridge to be moved consisted of four spans, each 172 feet clear, and 189 feet $9\frac{3}{4}$ inches centre to centre, giving a total length of 759 feet 3 inches. There were two main lattice girders, with cross-girders on lower flange, and six longitudinal girders. The gross weight of each span was 200 tons, and the total, therefore, 800 tons.

After the new bed-plates and rollers were ready, the whole of the girders were raised by hydraulic power about $1\frac{1}{2}$ inch, and the sliding beds were prepared on which the structure would move to its new position. The masonry of the abutments and piers was cleared as much as possible, and provision made for temporary connection of the rails across the two abutments. These preparations being completed, the apparatus for the actual moving of the structure was attached to the girders. Underneath the end of each span, as near as possible to the pier, a strong triangular timber framing with wrought-iron tie-rods was bolted on, clamping the whole of the girders. A powerful screw with linked coupling passed through the centre of this framing, and terminated in a wrought-iron strap passed round the end of the pier, which was properly protected by timbering. As the screw was tightened up, the framing carrying the superstructure of the bridge was drawn towards the end of the pier. Each of the four spans being fitted with two screw-frames, there were thus eight points at which the lateral pressure was applied. In order to ensure the equal and simultaneous application of the power at all points, a stationary engine was employed; this was placed on the bridge itself at one end, with a connecting-rod running the entire length of the structure. Upon this were bolted the heads of the lever-arms, by which, through a ratchet and pawl gearing, rotatory motion was given to the nuts by which the several screws were tightened up. To avoid the sudden jerk which would have accompanied the return of each stroke when the pressure on the toothed nut was removed, a counterbalance weight was suspended from the further end of the connecting-shaft. At each stroke of the engine the nuts were screwed up one tooth further, giving a lateral motion of about 0.04 inch to the screw-frames. Owing to the circumstances of the case it was impossible to test the efficiency of the arrangement as a whole before operations actually commenced, but every provision was made against failure of any part of the machinery. When the work of shifting the bridge was at last undertaken

very little irregularity was experienced, and all defects being speedily remedied, the whole structure was set in motion and successfully shifted into its new position—a lateral movement of 4 feet $8\frac{1}{2}$ inches—without hitch or accident; the whole work, including the restoration of the permanent-way connection and the roadway, being accomplished in the short space of four hours. After moving the old bridge there remained the new structure to be got into place, i.e., to be moved a distance of about 6 feet: but as everything had been duly prepared for this process, and there were no restrictions as to impeding traffic, this was done without difficulty.

P. W. B.

Railway Bridge over the Masnedsund (Denmark).

(Zeitschrift des Vereines deutscher Ingenieure, 1887, p. 651.)

This bridge, carrying a single line of railway over the Masnedsund, consists of two fixed spans each 198 feet, and a swing-span 107 feet 8 inches over all, on a central pier 24 feet in diameter, giving two openings of 60 feet clear width. The superstructure comprises two side main girders with cross girders on the lower flange, overhead cross-bracing, and diagonal wind bracing above and below. In the swing bridge the upper flange has a parabolic elevation; and the total weight, about 118 tons, is carried half on the central pivot, and half on sixteen conical steel rollers. The roller path is 17 feet 4 inches in diameter; the lower bed of cast-iron is anchored through to the masonry of the pier, while the upper plate, forming the bed-plate of the girder, consists of wrought-iron, and is riveted to the superstructure. The weight of metal in the superstructure is:—

	Wrought Iron.	Cast Iron.	Steel.
	Tons.	Tons.	Ton.
In two side-spans	362·60	10·58	1·47
In central swing-bridge	99·27	21·36	0·25
Total	461·87	31·94	1·72

The cost was about £9,600. The swing-bridge is worked by hand-winch, being opened or closed (including raising or lowering on locked bearings) by two men in two and a quarter minutes.

P. W. B.

The Datum Point in Railway Sections. By Prof. A. LORENZ.

(Zeitschrift des Österreichischen Ingenieur- und Architekten Vereines, 1887, p. 155.)

The Author, having in view the desirability of assimilating as far as possible to one standard the practice of engineers in all matters affecting railway construction, enumerates the different modes in which the levels in railway works are expressed in different parts of Europe. In England, France, Russia, Italy and Italian Switzerland, the datum point is stated in reference to the head or upper surface of the rails, while for constructive purposes the formation-level also is quoted. In Belgium the general practice for contract purposes is to give only the formation-level, but for all matters connected with the working of the line, the rail-head is stated. In the State lines in Prussia, Saxony and Wurtemberg, the level referred to in sections is the upper edge of the rails; in Saxony the foot or underside of the rail is also quoted for constructive purposes as the formation-level. In the Royal Bavarian State Railways and the Swiss (German Cantons) lines, the only level given is the upper edge of sleepers. In Austria-Hungary all levels, for both constructive and working requirements were originally made to refer to the rail-head; but in 1857 the first departure from this practice was made in the adoption of the sleeper level on the Southern railways system. At present a great number of the lines in Austria-Hungary take this as the standard, amongst them being all Hungarian lines, the North Western Railway, the Mährisch-Silesian Central Railway, the Bohemian lines, and the Meran to Botzen line. The Southern Railway itself has of late years returned to the use of the rail-head, on account of the variety of depths of rail section in use. Amongst the lines in Austria which have always adhered to the rail-head as standard are: the Northern Railway, the State lines, the Karl-Ludwig Railway, and the line from Aussig to Teplitz. On the Vienna-Anspang line, only the formation-level is quoted, and the rail-level is given as 1.56 foot higher.

By the regulations of the Imperial and Royal (Austro-Hungarian) General Inspection of railways, the formation level only has to be shown in preliminary projects. Detail sections are to show the surface of sleepers, which is the standard during construction. For all working purposes the standard of reference is to be the rail level.

P. W. B.

On the Consumption of Sleepers on Railways in France.

By H. MATHIEU.

(Revue Générale des Chemins de fer, 1887, p. 79.)

In previous articles, the Author had shown that the consumption of sleepers for the maintenance of the way, per mile of single line of the principal railways per annum, did not greatly differ, in the period of five years 1878-82, and the two years 1883-84; and that it ranged between 90 and 100 sleepers.¹ The length of way was reckoned as that of the railways, single and double, plus that of the double way, not including accessory ways, as sidings and other accommodation; but the renewals of sleepers on the sidings, &c., renewed, are included in the numbers renewed. The accessory length of way averages 25 per cent. of the total length.

The consumptions of sleepers are now calculated, as before, for the railways of the six principal companies, and the State Railways, which together comprise 95 per cent. of the total length of railways in France.

The consumption of sleepers for maintenance only is given in the annexed summary:—

Year.	Total Number of Sleepers Consumed.	Total Length of Single Way Worked.	Sleepers Consumed per Mile of Single Way per Year.
	Sleepers.	Miles.	Sleepers.
1878-1882	13,746,460	93,303	147
1883	4,204,119	24,788	170
1884	3,641,441	25,687	142
1885	2,988,826	26,878	111
1886	2,432,662	27,897	89
Totals . . .	27,013,508	198,553	136

With respect to the preservation of sleepers, the superiority of creosoting is generally recognized. Some companies have for some years past, prepared all their sleepers without distinction with creosote; and it is probable that the augmented durability, indicated by the diminishing rate of consumption of sleepers, shown in the last column of the Table, is due, to a material extent at least, to the extending practice of preserving by creosote. It is due also, no doubt, to the employment of chairs of large area of base; and affected also by the mode of fastening to the sleeper, and the nature of the ballast.

¹ Minutes of Proceedings Inst. C.E. vol. lxxix. p. 398.

The total number of sleepers supplied to the railways, in 1886, was 2,852,543, of which 11 per cent. were imported from other countries. The sleepers were of different woods as follow :—

Sleepers, 1886.	
Oak	1,655,033
Beech	656,802
Pine and fir	540,708
Total	<u>2,852,543</u>

Metal sleepers do not make progress in France. In 1886, about $2\frac{1}{2}$ miles of single way were on trial on the State lines.

D. K. C.

On the Value of Pickling Sleepers. By J. RIBAR.

(Zeitschrift des österreichischen Ingenieur- und Architekten Vereines, 1887, p. 14.)

The advantage of pickling sleepers has often been insisted upon, but the recently published statistics of the Austro-Hungarian lines show that it is not universally recognized, for of the 1,265,689 hard wood and 449,688 soft wood sleepers laid on Austrian lines in 1884, only 526,986 hard wood and 174,895 soft wood sleepers, or 40 per cent. of the total quantity, were pickled; while on Hungarian lines the proportion is much smaller, only 17,645 out of a total of 1,059,426 hard wood sleepers (about 1·6 per cent.) being pickled. It has been urged that in these countries, where timber is so plentiful, it is not worth while pickling the sleepers; but the results of the introduction of pickling on the "Südnord deutschen Verbindungsbahn" (1870 to 1886), as recently published, afford strong evidence on the other side. Of its total length of about 177 miles only 15 per cent. is level; while 23 per cent. has gradients of $\frac{1}{200}$ to $\frac{1}{100}$, and 33 per cent. has gradients of $\frac{1}{100}$ to $\frac{1}{50}$. Again, of the total length 55 per cent. is straight; 13 per cent. with curves of over 25 chains radius; 20 per cent. with curves from 25 to 15 chains radius; 12 per cent. with curves from 15 to 10 chains radius. In 1870 the line was laid entirely with iron rails, of the section used on the State railways, and weighing 72·6 lbs. per yard. In this year relaying with steel rails commenced, and by 1885 the whole main line was re-laid with steel rails. Two new connecting lines opened in 1875 were laid with iron rails of the standard section of the Austrian North-Western Railway, weighing 69·5 lbs. per yard. At the end of 1886, 23·3 per cent. of these had been replaced by steel. The iron and the earlier steel rails had solid resting joints, and on straight lengths and curves of more than 30 chains radius there were bearing-plates only at the joint and at the centre of each rail; but in sharper

curves there were bearing-plates on each sleeper. The later steel rails had suspended joints. For the last four years it has been the practice to use bearing-plates on every sleeper, whether in curves or straight lengths, as they are found to protect the sleeper very much.

From 1870 to 1878 the sleepers were made of red-wood (*Fichte*), white-wood (*Tanne*), and fir (*Kiefer*—*Pinus sylvestris*). Since 1878 only pine has been used; it is obtained from forests in the neighbourhood of the line, and is of average quality. The sleepers were first pickled for use in 1877 on the Burnett system, a solution of zinc chloride (density 3° Beaumé) being used, also a mixture of 94 per cent. of this solution with 6 per cent. of creosote oil. In 1880 a weaker solution (1½° Beaumé) of zinc chloride, to which was added 3·3 lbs. of creosote oil per sleeper, came into use; the cost of the former method was from 10½d. to 1s. 0½d., of the latter 8d. per sleeper. The contractor has to guarantee red-wood and white-wood for seven years, and fir for nine years, but only in so far that he has to creosote a new sleeper free of cost for every one which fails by rotting during the period of his guarantee.

The ballast is only good in those portions of the line made in 1875, the remainder being land gravel not free from loam, and broken sandstone (*Rothliegende*), which falls after short exposure to the weather. The ballast is consequently most unfavourable to the endurance of the sleepers. It is being gradually replaced.

The traffic on the line is fairly heavy (the receipts of last year were about £1,600 per mile). The passenger trains run at a speed of 25 miles an hour. The goods trains are drawn by four-axled engines, weighing 42 tons.

The Table on the following page gives full particulars of the sleeper changes from 1870 to 1886.

In this Table the results to 1886 are those of actual experience, but in order to show the result of using only pickled sleepers the Table is continued on to 1893 by using data obtained from other lines of railway.

Taking the figures given in this Table together with a graphic Table which the Author gives, he finds that the whole of the unpickled sleepers were changed in seven years, whereas the pickled sleepers will not be all changed until the expiry of a period of from thirteen to fifteen years. The consequent saving in expense will enable more to be spent in replacing bad ballast and extending the use of bearing-plates for the rail on the sleepers, and thus still further prolong the life of the sleepers.

The graphic Table shows the great superiority of pickled fir (*Kiefer*) over pickled red-wood (*Fichte*) and white-wood (*Tanne*), for after eight years only 4·7 per cent. of the latter had to be changed, but 20·9 per cent. of the former.

The experience of the Austrian North-Western Railway with oak sleepers also is in favour of pickling.

Year.	Length of Line Open.	Sleepers.		Percentage.			Cost in Florins.				
		Pickled (P), or Unpickled (U).	Number.		Unpickled.	Pickled.	Total.	Materials.		Labour and Materials.	
			In Line.	Defective.				Total.	Per Kilo- metre.	Total.	Per Kilo- metre.
	Kilo- metres.										
1870	225·833	U	313,646	54,739	17·4	..	17·4	38,635	171	49,583	220
1871	225·833	"	313,646	53,748	17·1	..	17·1	39,867	177	50,617	224
1872	225·833	"	313,646	56,766	18·1	..	18·1	49,069	217	60,422	268
1873	225·833	"	313,646	61,766	19·7	..	19·7	57,146	253	69,499	308
1874	225·302	"	313,646	82,561	26·3	..	26·3	70,159	311	86,661	384
1875	285·070	"	357,952	67,029	18·7	..	18·7	70,145	246	83,551	293
1876	285·070	"	357,952	69,660	19·4	..	19·4	77,886	273	91,818	322
1877	285·070	"	357,952	64,818	18·1	..	18·1	88,428	310	101,392	391
1878	285·070	{ U	325,529	35,905	11·03	} 0·00	} 10·3	} 52,566	} 184	} 59,747	} 210
		{ P	32,423	..							
1879	285·070	{ U	294,183	54,383	18·48	} 0·00	} 15·2	} 77,055	} 270	} 87,932	} 308
		{ P	63,842	..							
1880	285·070	{ U	240,276	63,452	26·41	} 0·00	} 17·7	} 78,700	} 276	} 91,390	} 321
		{ P	118,214	..							
1881	285·070	{ U	181,757	59,591	32·78	} 0·00	} 16·7	} 71,471	} 251	} 83,389	} 293
		{ P	174,782	..							
1882	285·070	{ U	115,220	47,955	41·62	} 0·09	} 13·4	} 60,853	} 213	} 70,489	} 247
		{ P	243,044	225							
1883	285·070	{ U	64,582	30,578	47·34	} 0·30	} 8·8	} 44,112	} 155	} 50,403	} 177
		{ P	289,460	877							
1884	285·070	{ U	34,004	15,044	44·09	} 0·52	} 4·6	} 36,617	} 93	} 29,964	} 105
		{ P	324,403	1,692							
1885	285·070	{ U	19,714	8,465	42·94	} 1·12	} 3·4	} 22,079	} 75	} 24,538	} 86
		{ P	343,107	3,829							
1886	285·070	{ U	11,252	9,800	87·09	} 1·41	} 4·1	} 23,000	} 80	} 25,960	} 91
		{ P	354,041	5,000							
1887	285·070	{ U	1,500	1,500	100·00	} 2·58	} 3·0	} 21,200	} 70	} 23,380	} 82
		{ P	364,000	9,400							
1888	285·070	{ U	366,200	14,700	..	} 4·00	} 4·0	} 23,000	} 80	} 25,940	} 91
		{ P	366,600	20,200							
1889	285·070	"	366,700	28,600	..	5·50	5·5	31,000	108	35,040	123
1890	285·070	"	366,700	28,600	..	7·80	7·8	41,000	144	46,720	164
1891	285·070	"	367,000	36,700	..	10·00	10·0	53,000	186	60,340	212
1892	285·070	"	367,000	45,875	..	12·50	12·5	66,250	233	75,425	265
1893	285·070	"	367,000	55,050	..	15·00	15·0	79,500	279	90,510	318

Note.—100 florins per kilometre = about £15 15s. per mile.

W. B. W.

The Zinc-Creosote Process of Preserving Railway Timber.

By J. P. CARD.

(Journal of the Association of Engineering Societies, 1887, p. 257.)

In this Paper, which was read before the Western Society of Engineers, Chicago, Mr. Card, after having summarily noticed the processes of wood-preserving by kyanising, Boucherising, Burnett-

ising, and creosoting, gives an account of what is called the zinc-creosote process. On this system, dead-oil and chloride of zinc are used in combination, for the preservation of railway-sleepers and timber, as well as for protection against the attacks of the teredo in sea-water.

For railway-sleepers, bridge-timbers, and the like, where the wood is not exposed to any considerable degree of moisture, after the timber is prepared in the usual way by steaming and vacuum, the dead-oil is run into the cylinder, and so much as may be desired is forced into the wood. For this purpose, Mr. Card recommends the proportion of half a gallon of oil per cubic foot of timber; though a smaller proportion may be found to answer. After the timber is treated with oil, the oil is withdrawn from the cylinder, which is then charged with chloride of zinc, which by pressure can be forced into the wood through and beyond the oil, impregnating by diffusion that portion of the wood which is not penetrated by the oil, specially useful in the case of ill-seasoned or dense timber. By such combined operations, the wood, when it is in contact with the ground or other moist surface, receives the benefit of the dead-oil treatment, with an expenditure of one-half or even less than half the usual proportion of oil; whilst those portions unreached by the oil are impregnated with the zinc-chloride. The chloride, surrounded by the oil, is protected for a lengthened period against moisture. By this process, the half measure of oil can be as widely diffused through the substance of the wood, as the whole measure by the ordinary creosoting treatment.

Mr. Card concludes, from his observations and experiments, that the zinc-creosote injection will give the best results for the money invested.

D. K. C.

The Economic Value of Iron and Steel Sleepers.

By W. HOHENEGGER.

(Organ für die Fortschritte des Eisenbahnwesens, 1887, p. 142.)

Having had ten years' experience of iron sleepers on the Austrian North-Western Railway, the Author considers that it is time to consider their economic value, and not only, as hitherto, their technical value.

The first suggestion of an iron longitudinal sleeper-permanent-way, was at the Vienna Exhibition of 1873, and the Author was instructed to design one suitable for the Austrian North-Western lines. The result was a longitudinal sleeper of trapeziform section, without a middle rib, and with wedge-shaped thickenings at the lower ends of the side-wings. The same section has since been used for iron cross-sleepers on the St. Gothard, and various German and foreign railways.

About $2\frac{1}{2}$ miles of line was laid in 1876 with these longitudinals with cross-sleepers of the same section under their joints. This

has answered very well, only one sleeper having failed in the ten years to 1886. The cross-sleepers at the joints had, however, to be taken out after a few years, and be replaced by angle-irons, as it was found that they gave too much support at the joints, and thus set up a wave motion in the trains.

The great cost of this permanent-way (£1 6s. 3d. per lineal yard, as compared with £1 0s. 6d. per lineal yard, for a road with pickled oak sleepers), determined the Author to introduce a longitudinal sleeper rolled from two old flat-bottomed rails, the heads being placed together, and the feet forming the two wings of the sleeper. The permanent-way laid with these sleepers cost £1 0s. 10d. per lineal yard, but the sleepers were not so good as those rolled from properly prepared piles. It was found that the welding of the two heads was frequently faulty, and the sleeper was also weak at the points corresponding with the bearings of the old rails. These old rail sleepers were made and laid so long as there were good weldable Scotch rails amongst those annually taken up in relaying, a total length of thirteen miles being laid with them in 1877-1881.

The supply of suitable old rails being then exhausted, and the introduction of the Thomas process into Austria having rendered steel cheaper, an improved sleeper and fastenings,¹ was introduced by the Author, and about 36 miles relaid with it in 1882-1885. This system costs £1 1s. 3d. per lineal yard. In five years' wear of these lengths, no sleeper, cross-tie or fish-plate, has had to be changed; while the renewal of bolts per autumn has only been $\frac{1}{10}$ of what it was with the earlier design of iron longitudinal. No instance of a broken rail has occurred during the ten years in which the iron and steel longitudinal sleepers of the three systems abovenamed have been in use. For a comparison of the cost of maintenance of the road laid on wooden sleepers, the Author takes the guaranteed lines of the Austrian North-Western and the complementary lines of the same railway for the year 1885.

The patterns of rail, the kind of wood sleepers, the weight of traffic, and the speed of trains being about the same on the two systems render them very suitable for comparison. Of the 200 miles of the main line of the guaranteed lines, only three are laid with iron longitudinals, while of the 84 miles of the main line of the complementary lines, 45 are laid with iron longitudinals.

TABLE I.

	Length. Miles.	Cost per mile of Maintenance in 1885.								
		Labour.			Iron Materials.			Sleepers.		
Guaranteed lines . .	389.4	£	s.	d.	£	s.	d.	£	s.	d.
		19	13	4	16	16	1	39	15	10
Complementary lines . .	191.2	£	s.	d.	£	s.	d.	£	s.	d.
		22	5	4	18	6	2	8	17	6

One florin taken = 1s. 11½d.

¹ Described in the *Organ für die Fortschritte des Eisenbahnwesens*, 1883, p. 1.

This Table gives the cost of maintenance of the permanent way exclusive of relaying.

The following Table gives particulars of the wood sleepers on the guaranteed lines in 1885 :—

TABLE II.

Kind of Wood.	Pickling.	Total Number of Sleepers.	Sleepers changed.		
			Number.	Per cent.	Average life. Years.
Oak	Creosote.	306,912	853	0·27	7½
"	None.	324,583	61,355	18·90	10½
Fir (Kiefer) . .	Creosote.	231,815	4,107	1·77	7½
" " . . .	None.	16,010	6,466	40·38	10
Total		879,320	72,787	8·28	

At the close of 1885 the permanent way was as follows :—

TABLE III.

Material of.		Guaranteed Lines.		Complemental Lines.	
Rail.	Sleeper.	Miles.	Per cent.	Miles.	Per cent.
Iron.	Wood.	92·4	23·7	70·3	36·9
Steel.	Wood.	294·0	75·5	75·2	39·3
Steel.	Iron or steel.	3·0	0·8	45·7	23·8
Total		389·4	100·0	191·2	100·0

Of these lengths there were laid during 1885—

TABLE IV.

On the Guaranteed Lines .	18·8 miles.	Steel rails in place of iron rails.
" Complemental Lines.	9·4 "	" " "
" " " .	6·3 "	{ Steel rails and sleepers in place of iron rails on wood sleepers.

The cost of this is not included in the statement of the cost of maintenance given above (Table I).

The cost of maintenance per mile, exclusive of relaying, was in 1885—

TABLE V.

	Guaranteed Lines.		Complemental Lines.	
		Per cent.		Per cent.
Wages	..	25·8	..	45·0
Iron material . . .	..	22·0	..	37·0
Wood material. . .	..	52·2	..	18·0
Total	£76 5 4	100·0	£49 9 1	100·0

Florin taken as = 1s. 11½d.

Assuming a life of thirty years for the steel sleepers, and allowing for the year 1885 its proportion of the additional cost of steel over wood sleepers, the cost per mile of maintenance of the supplemental lines is £51 8s. 1d. per mile, or 67 per cent. of the cost of maintenance of the guaranteed lines.

It is seen (V) that the cost of labour per mile is higher in the supplemental lines than on the guaranteed lines. This is owing (III) to the larger proportion (36·9 per cent.) of old iron rails on wood sleepers, remaining on the former line as compared with 23·7 per cent. of the total length on the latter. In spite of this the cost of maintenance is only 67 per cent. of that of the guaranteed lines, thus showing what a great influence the cost of renewal of wood sleepers has upon the cost of maintenance, and what saving can be effected by the extended use of steel sleepers in spite of their high cost.

After claiming superiority for longitudinal steel over wood cross sleepers on various other grounds, the Author urges the adoption of steel on national grounds. The railways of Austria-Hungary in 1884 used 2,774,803 sleepers, valued at £320,000, exclusive of creosoting, or other impregnation. This sum is lost to the country every year, whereas it might be saved to the national purse were the wood sold to foreign countries and steel sleepers of home manufacture used instead. If the forests continue to be plundered as is now being done, the supply will not last, whereas the extended use of steel sleepers would revive the iron trade, which is now in such a depressed condition.

W. B. W.

A New Steel Sleeper.—By J. W. Post.

(Organ für die Fortschritte des Eisenbahnwesens, 1887, p. 108.)

This is an improvement on the steel sleepers of variable cross section described in Organ für die Fortschritte des Eisenbahnwesens, 1885,¹ three hundred thousand of which are in use upon German, French, Belgian and Dutch lines.

¹ Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 496.

The thickened and sloping seat for the rail and the ends of the sleeper closed in without stamping out the angles remain as before; but about $33\frac{1}{2}$ inches from the end of the sleeper, which is 8 feet 6 inches long, it commences to narrow in, at the same time increasing in depth, until at the middle the width over all is reduced from $9\frac{1}{4}$ inches to $5\frac{1}{2}$ inches, the depth being increased from $2\frac{1}{4}$ inches to $4\frac{3}{4}$ inches. The narrowing of the sleeper in the middle reduces the resistance of the sleeper-bed in the middle, and so causes the sleeper to be supported most firmly immediately under the rails. This is especially an advantage where the ballast is not properly beaten up, for where a sleeper is the same width throughout it may come to be supported most strongly in the middle, and so develop a rocking motion, while as the narrowed sleepers sink in the ballast the chief support will be under the rail.

The increased depth in the middle is also of advantage in increasing the resistance of the sleeper to bending.

The narrowing of the sleeper also increases its resistance to moving sideways, but the closed ends already adopted in the older design are found to be quite efficient in preventing such motion.

The alteration in the form of the sleeper increases the cost about 5s. per ton, and so far experience of the new pattern proves the advantage gained to be worth the additional cost.

In the sleepers of this pattern made for the Netherlands State Railways for the year 1887, a further experiment has been made in heating the rail-bed of the sleeper after the bolt-holes have been punched, to determine whether the advantage gained by thus doing away with the brittleness induced by punching is worth the cost of the operation.

Professor Tetmajer finds that for steel with a tensile strength of 28 to 32 tons per square inch, by heating the punched holes, there is a gain of about 25 per cent. in tensile strength, 100 per cent. in resistance to breaking by a falling weight, and 200 per cent. in resistance to splitting by bending.

Of the ninety-five thousand sleepers of the new pattern laid on the Netherlands State Railways not one has so far broken. This may not be attributable to the reheating after punching, but there can be no doubt that it is beneficial, and it is probable that if the system is adopted a somewhat harder steel than that now in use might be used for sleepers. The cost is but a few pence per sleeper.

The ninety-five thousand steel cross-sleepers named above, with the varying cross section and weighing 110 lbs. each, have proved satisfactory, even on the lines where the traffic is fastest, *e.g.*, between Flushing and Venlo, where engines of 67 tons weight run at 46 miles an hour.

In 1886 the Company laid between Tilburg and Breda a trial length of heavier permanent way, taking advantage of the low price of steel. Its great cost prevents the general adoption of the new design, though even at present prices it appears to be suitable

for lines with heavy traffic. The rails, which weigh 80·6 lbs. per yard, are 5½ inches deep and 39·4 feet long. In the 39·4 feet length there are fourteen cross sleepers spaced at irregular intervals, and weighing 110·7 lbs. each. The holding-down bolts are 1 inch in diameter. This permanent way weighs 320·5 lbs. per lineal yard as compared with 266·1 lbs., the weight per lineal yard of the normal pattern, in which the rails weigh 68 lbs. per yard. The former cost 13s. 9d. per lineal yard, exclusive of laying and ballasting, and the latter 11s. 4d.

W. B. W.

On the Influence of Intermediate Tuyeres in the Blast-Pipe of Locomotives. By PROFESSOR ALBERT FLIEGNER.

(Schweizerische Bauzeitung, 1887, No. 5, p. 27.)

The Author's object is to investigate the influence, if any, of tuyeres in connection with the blast-pipe on the production of the draught, and develop rules for the construction of the same. The investigation is an extension of the well-known theory of Zeuner, and is based on the same approximations as the latter, with one exception.

In order to give the theory in a more general form, two tuyeres one above the other are assumed; these are supposed to be cylindrical for a certain portion of their length, but contracted towards the top.

It is assumed that the pressure in the smoke-box is the same at all points, and as the differences of pressure causing motion are small, the pressures in the planes of the orifices F , F_1 , F_2 , and F_3 , of the blast-pipe, tuyeres, and smoke-tubes respectively, may be taken as equal to that in the smoke-box. In the same way the pressure at the mouth of the chimney can be considered equal to that of the atmosphere p_0 .

Let p denote the pressure above the atmosphere in the blast-pipe, including an equivalent for the velocity of the steam where this is high; p , the vacuum in the smoke-box (absolute pressure $p_0 - p$).

All other pressure p_i are less than atmospheric pressure, their absolute value is therefore $p_0 - p_i$.

D the weight of steam flowing out per second.

L the weight of fire-gases drawn through per second.

L_1 , L_2 , L_3 , the portions of the fire-gases which pass respectively between the blast-pipe and first tuyere, between the tuyeres, and between the second tuyere and the chimney.

F_1 and F_2 respectively the areas of the mouths of the first and second tuyeres.

F_1' and F_2' respectively the areas of the cylindrical portions of the first and second tuyeres.

$$\frac{F_1'}{F_1} = a_1; \quad \frac{F_2'}{F_2} = a_2 \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot (1)$$

The density γ of the gases is assumed to be constant throughout, and hence the velocities w may be calculated by the usual hydraulic formula.

The different velocities, coefficients of resistance, and pressures, are denoted by the same indices as the sectional areas to which they apply.

The flow of steam through the blast-pipe is found from the equation:—

$$(1 + \zeta) \frac{w^2}{2g} = \frac{w^2}{\phi g} = \frac{p + p_r}{\gamma}; D = F w \gamma; \dots (2)$$

and that of the fire-gases through ash-pan, grate, fuel, and tubes, by

$$(1 + \zeta_r) \frac{w_r^2}{2g} = \frac{w_r^2}{\phi_r g} = \frac{p_r}{\gamma}; L = L_1 + L_2 + L_3 = F_r w_r \gamma; (3)$$

The weights of steam and gases passing through the first and second tuyeres respectively are expressed by the formulas

$$D + L_1 = F_1' w_1' \gamma = F_1 w_1 \gamma; w_1' = a_1 w_1; \dots (4)$$

and

$$D + L_1 + L_2 = F_2' w_2' \gamma = F_2 w_2 \gamma; w_2' = a_2 w_2; \dots (5)$$

Through the chimney passes the quantity

$$D + L = F_* w_* \gamma = F_o w_o \gamma = F w \gamma + F_r w_r \gamma; \dots (6)$$

where F_* and F_o are respectively the sectional areas of the chimney, corresponding to the least diameter and that at the top.

From these fundamental formulas as a basis, and by the aid of the well-known relation existing between pressure and velocity in different parts of the apparatus, the Author develops expressions for w_1 and w_2 , the velocities in the planes of the tuyere-orifices F_1 and F_2 . Zeuner, in his work on this subject, takes it for granted that the steam and gases in traversing a conically divergent chimney meet with no resistance. At the time his work was written there were only a few experiments of Weisbach extant on the influence of gradual enlargements in pipes, and these showed no noticeable resistance.

More extended experiments, carried out by the Author himself, on the effect of enlargement in pipes,¹ have, however, proved that while a gradual enlargement reduces the resistance more or less at low velocities, with sufficiently high velocities the resistance is as great as for a sudden increase of section.

The cause of this is, that with increasing velocity the natural cone of the jet of fluid becomes more acute, so that at last it remains entirely within the most gradual pipe-enlargement. In that case the diverging walls have no effect on the motion of the

¹ "Civilingenieur," vol. xxi.

jet, which takes place as though the increase of sectional area were sudden. Conversely, with a given velocity of flow, a gradual enlargement will only cause a reduction of the resistance when the walls come within the natural cone.

These experiments were made with water, but in so far as elastic fluids have been investigated their behaviour is quite similar.

The question as to the amount of resistance caused by a conically divergent chimney depends on the relation which the form of the latter bears to that of the free jet. Zeuner found the angle of divergence of a jet of steam escaping into the air under pressures of $\frac{1}{2}$, 1, and $1\frac{1}{2}$ atmospheres, to be respectively $24^{\circ} 4'$, $21^{\circ} 36'$, and $20^{\circ}-24'$.

The Author considers that, taking into account the effect of the hot gases on the steam, it will be near the truth to assume that the natural angle of divergence of the mixture escaping from a locomotive chimney is 20° .

The maximum divergence in practice of a locomotive chimney known to the Author is about 10° , consequently within the natural angle. As, however, the contraction of the natural form of the jet is not great, the Author considers that the loss of energy due to the reduction of the velocity is not negligible, and makes the assumption that the energy actually lost is a certain fraction ϵ of that which would be dissipated by the free development of the natural cone. The latter quantity may be expressed by $\frac{(w_n - w_o)^2}{2g}$.

Hence the equation for the energy of the fluid in the chimney has the form :

$$\frac{w_n^2}{2g} + \frac{p_o - p_n}{\gamma} = \frac{w_o^2}{2g} + \frac{p_o}{\gamma} + \frac{\epsilon (w_n - w_o)^2}{2g}.$$

By a series of mathematical combinations the Author arrives at the following formula expressing the ratio of the pressure in the blast-pipe to that in the smoke-box :

$$\frac{p}{p_r} = \frac{\alpha (\kappa^2 + \phi_r \lambda \mu^2)}{\phi (\kappa - \alpha \lambda)} - 1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

in which the abbreviations are introduced :

$$\alpha = \frac{1 + \zeta_1 + a_1^2}{2 a_1} \cdot \frac{1 + \zeta_2 + a_2^2}{2 a_2}$$

$$\kappa = \frac{F_n}{F}$$

$$\lambda = \frac{1}{2} \left[1 + \left(\frac{F_n}{F_o} \right)^2 + \epsilon \left(1 - \frac{F_n}{F_o} \right)^2 \right]$$

$$\mu = \frac{F_r}{F}.$$

For any particular locomotive under given conditions, the weight of steam passing out of the blast-pipe is determined, and to produce this a certain weight of fire-gases must leave the tubes; in order, however, that this quantity may really be drawn through, the vacuum p_r in the smoke-box must have a certain value.

The equation (21) shows that this value of p_r may be attained with different values of p the pressure in the blast-pipe, according to the dimensions of the blast-apparatus. For economical reasons, p should be as low as practicable. Zeuner has determined the best value for κ the ratio of the lower chimney area to that of the blast-pipe orifice, for μ there is no specially favourable value; there remain the quantities α and λ to be dealt with. α depends on the proportions of the tuyeres; the Author proves mathematically, that the best value of α is obtained by using cylindrical tuyeres, in which case α also becomes 1. The conclusion drawn is, that the best form for the tuyeres is cylindrical, in which case they have no influence on the action of the blast-apparatus as a whole; if the tuyeres are convergent or divergent, the pressure in the blast-pipe is increased.

The use of tuyeres consists in their insuring the necessary vacuum in the lower part of the smoke-box, and thus securing a more uniform distribution of the gases in the smoke-tubes.

The requirement of a cylindrical form for the tuyeres applies only to that portion of the length in contact with the steam-jet, below they may be enlarged.

The dimensions of each tuyere are determined with reference to the distribution of the gases.

The value of λ depends on the proportions of the chimney, and the coefficient of loss ϵ ; it should be a minimum, which occurs for

$$\left(\frac{F_1}{F_0}\right) = \frac{\epsilon}{1 + \epsilon} \text{ and } \lambda = \frac{1 + 2\epsilon}{2(1 + \epsilon)}.$$

This result differs considerably from that obtained by Zeuner, and shows that the resistance or loss of energy in the chimney has great influence on the best dimensions for the latter.

The Author considers that a ratio of the upper to the lower diameter of $1\frac{1}{2}$ would be approximately correct, but for an accurate determination experiments on the value of ϵ would be necessary; for a series of values of the latter, the corresponding figures for

$\frac{F_1}{F_0}$, $\frac{d_1}{d_0}$ and λ are given in a tabular form.

G. R. B.

The Age of Locomotives on the Normal-Gauge Railways of Germany. By — LEONHARDT.

(*Annalen für Gewerbe und Bauwesen*, Aug. 15, 1887, p. 68.)

The number of engines in use on German railways at the end of the railway year 1884-85,¹ was 12,098; and, at the end of the railway year 1885-86, was 12,450; the cost of these engines is given at 581,097,313 marks and 588,551,463 marks; or, the cost per locomotive, including tender, 48,033 marks in 1884-85, and 47,273 marks in 1885-86 (£2,400 and £2,363 respectively). During the past year the total number has been increased, but only thirty-three new engines have been added. The mean age of the locomotives in use during the year of service 1884-85 was 12·60 years; and in 1885-86 12·49 years. This is deduced from a table of the number of engines added and in active use for each year from 1843 to 1885. From this table it follows that fifty-nine engines built prior to the year 1850 were running during the year 1885-86, and that the distinction of being the oldest running engine in Germany falls to one on the Holsteinische Marschbahn, which dates back to 1845. An examination of the table shows also that the average number of engines still extant is under one hundred for each year prior to 1857; from 1858 onwards the number rises steadily. Thus, in the year 1885-86 there were still two hundred and ten locomotives which began work in 1864. In the next few years the increase in numbers is still more rapid, and reaches in 1874 a maximum of 1,478 for the year 1884-5, and 1,464 for the year 1885-6. From 1878 until 1880, there is a steady decrease, which attains the minimum in the latter year. There were one hundred and thirty-one engines of 1880 in 1884-5, and one hundred and thirty-two engines of 1880 in 1885-6. The subsequent numbers again rise to over five hundred for 1883; thus there were five hundred and seventeen engines which began work in 1883 in use during 1885-6.

G. R. R.

Rolling-Stock for Sharp Railway Curves. By G. T.

(*Le Génie Civil*, vol. xi., 1887, p. 288, 5 woodcuts.)

The resistance to traction of the ordinary rolling-stock is doubled on curves of ten chains: the rails and tires wear rapidly on sharp curves; and the speed has to be reduced, for fear of the train running off the line. Colonel de Bange has proposed a new arrangement of wheels for facilitating the running over sharp curves, so important for railways in mountainous districts. The

¹ On most German railways the account-year runs from the 1st of April in one year till the 1st of April following.

axles are fixed; and the wheels turn on axle journals of such a shape that, whilst resting on the wheels through the interposition of a cushion, they admit of the wheels turning on a vertical axis which is in a line with the point of contact with the rail. The cushion is furnished with a cylindrical projection which, fitting into a recess in the flat base of the axle, serves as a pivot, enabling the cushion to follow the slight horizontal rotation of the wheel, whilst attached to the axle by two bands. By this arrangement, the wheel always assumes a position tangential to the rail; and by combining this with a longitudinal play of the axles, a vehicle with any number of axles could run round a very sharp curve. This arrangement, moreover, enables the full amount of adhesion to be given to locomotives, combined with a long wheel-base, a great gain for engines designed to run on lines with sharp curves, which often have steep gradients as well. A method of coupling the wheels, whilst leaving them free to adapt themselves to the curves, has been adapted to a small eight-wheeled locomotive, weighing 10 tons, and tried in the workshops of the Cail Company in Paris, the axles being arranged for running round curves of only 40 feet radius. A rigid triangular connecting-rod is attached to the driving shaft, and guided by two cranks so that its motion is parallel to the frame; it carries a projecting bar opposite each wheel, inserted into a swivel table fastened to the wheel by a spring, so that the connecting-rod guides the wheel in whatever position it may be. The present rigid rolling-stock could be readily transformed into the proposed system. For vehicles, it would only be necessary to unfasten the wheels, fix the axles, and make the axle journals of the required form. For locomotives, the transformation would vary according to circumstances. Thus for example, with a six-wheeled coupled locomotive with inside cylinders, the front and hind wheels would be unfastened and their axles fixed, but the driving-wheels would not be altered; and two false axles, placed in a prolongation of the frame before and behind, would guide the coupling rods, worked by the driving-wheels and controlling the loose fore and aft wheels by their projecting bars, as in the trial locomotive. By this means, without great modifications, and by giving a slight longitudinal play to the end axles, a locomotive of the ordinary type employed by the railway companies could be adapted for running round curves of 3 chains radius.

L. V. H.

Petroleum-Refuse as Fuel on the Elevated Railroads of New York.

(American Machinist, Nov. 12th, 1887.)

On the elevated railroads of New York experiments have lately been made with petroleum refuse, used as fuel in one of the locomotives, with greater success than has been obtained hitherto. The dimensions of the furnace used were as follows:—length, 42½

inches; breadth, $3\frac{1}{2}$ inches; height, $4\frac{1}{2}$ inches. The trial trips of the engine were made by coupling it to one of the regular trains, and conveying passengers in the ordinary course. During the trips plenty of steam was made, no time lost, and everything worked most satisfactorily. With the present price of petroleum-refuse engines can be run much cheaper than with coal; but what the price of petroleum will become, should it be generally adopted as fuel, is a matter of doubt. The apparatus for burning the oil is extremely simple, and can be attached to a locomotive without changing any of its parts. Air is admitted into an inclosure of brickwork built up inside the furnace, and there allowed to mingle with a proportionate amount of petroleum-refuse and steam, so that a vapour is formed which is easily ignited. The petroleum and steam are injected into the inclosure by means of an apparatus consisting of a cylindrical shell and a hollow spindle. The front end of the shell is fastened to the back of the furnace. Oil is admitted into the shell near the front end, steam being admitted near the back; they are prevented from mingling by a rib cast to the inner surface of the shell midway of its length, and fitting the outer surface of the hollow spindle. By placing packing in front of this rib round the spindle two distinct chambers are formed in the cylindrical shell, the front being for oil and the rear for steam. The front end is closed by a cap, having a cast-iron nozzle in the centre of the front face, through which the oil flows. The end of the spindle fits into a taper hole in the nozzle, so that the supply of oil is regulated by advancing the taper end of the spindle into or withdrawing it from the taper hole in the nozzle; this is done by means of bevel gear worked by a hand-wheel placed on the end of a shaft projecting upwards through the foot-plate of the engine.

The steam enters the hollow part of the spindle through a hole drilled in the shell, and thence passes into the furnace, drawing the oil with it through the nozzle. The supply of steam is regulated by a globe-valve fixed on the steam-pipe leading to the injector.

Certain quantities of air are admitted into the furnace through the ash-pan, the supply being regulated by the dampers. When the air comes in contact with the oil and steam in the furnace, a vapour is formed which, being ignited, produces a flame of intense heat. As the direct impact of the flame is considered injurious to the plates of the fire-box, and the form of the present fire-box is not suited for the complete combustion of the vapour in the furnace, the inside is lined with brick, so as to form a suitable inclosure for the proper mixing of the air, oil and steam; and in this brickwork inclosure the vapour is ignited. The bottom of the ash-pan is lined with cement to prevent the heat from warping it, and the brick wall which runs parallel to the back tube-plate extended down to the bottom of the ash-pan, so that air cannot enter the front end of the brick inclosure. With the present arrangement it requires the constant attention of a skilful man to

regulate the supplies of air, oil, and steam in such degrees as will cause a complete combustion of the gas, and prevent smoke from issuing from the smoke-stack; but it is believed that if the refuse of petroleum is to be used as a fuel in locomotives, the apparatus can be made simpler, and will require less labour and attention on the part of the fireman.

L. H. R.

Distribution of Traffic on the French Railways, and the Cost Price of Transport. By G. RICOUR.

(Annales des Ponts et Chaussées, vol. xiv., 1887, p. 143, 2 diagrams.)

An official return is published in Paris every month, giving, for each section of the French railways, the total receipts and expenses, the receipts and expenses per kilometre, and, lastly, the ratio between the expenses and receipts, or over two hundred returns for a total length of 16,800 miles; the receipts per mile ranging from £83 to £12,760, and the expenses from £383 to £7,145. Grouping the lines together according to increasing receipts per kilometre, a diagram is drawn from the returns of 1883 with the receipts per kilometre as abscissas, and the coefficient of working, or the percentage the total expenses bear to the receipts, as ordinates; whilst the importance of each group, represented by the point at the extremity of each ordinate, is indicated by the length of an ordinate suspended at the corresponding point. The line joining the several points approximates closely to a regular curve; the only notable divergence occurring near receipts per mile of £2,230 to £2,870, corresponding to the place of change from single to double line, the lines to the right with large receipts being double lines, and to the left with small receipts being single lines. This same curve shows that a relation exists between the cost price of the unit of traffic and the amount of traffic; and it furnishes a graphic representation of this relation, as indicated more simply in the second diagram, where this relation is shown graphically for 1882 and 1883, and the close accordance of the two lines to the theoretical curve is clearly represented. The curve indicates rather too great values for receipts exceeding £7,975 per mile; but these receipts are restricted to a very small fraction of the French railways. The results obtained show a very remarkable equilibrium in the distribution of the whole of the traffic in France; and indicate that, in whatever way the traffic is divided between the various groups of lines of a system of railways, the cost price of a thousand units of traffic remains constant, provided the general average traffic is the same; and it appears from the returns of 1882 and 1883 that, in spite of the independence of the companies, the traffic was distributed as if a single company had regulated it according to the least cost. On the main lines, the trains are fully loaded, so that an increase of traffic necessitates

more carriages and more trains; whereas on the branch lines, the trains are much less well filled, so that in this case additional traffic merely uses the same trains to greater advantage, which renders the additional cost of an increase of traffic independent of the gradients, and equalises its distribution. A reduction in the cost price would enable the tariffs to be reduced, and attract some of the traffic to the French lines which at present passes over foreign railways; and this increase of traffic, by further reducing the cost price, would be of the greatest value now that the receipts per kilometre are being greatly lowered by the constant opening of fresh lines. That such a reduction may be possible is indicated by the economy of nearly 10 per cent. in working expenses effected by the Paris, Lyons, and Mediterranean Company, as compared with the general average of the French companies, and by the reduction of 18 per cent. in the cost of traction on the State railways by means of simple alterations in the existing locomotives and 12 per cent. by filling the carriages better, and thus diminishing the proportion of dead load. A similar reduction in all the branches of working expenses could alone give a prospect of prosperity in the future to French railways. Otherwise the increase of new lines, by affording more direct routes tending to reduce the units of traffic, and by raising the capital, will before long bring up the guarantees and annuities paid by the State to more than the dividends of all the French railway companies; for whilst the net receipts are reduced, every 1000 kilometres (620 miles) add an annual charge of about £800,000. The sole efficient remedy consists in stopping expenditure on the construction of unproductive lines, and in reducing the working expenses of the great systems of French railways.

L. V. H.

On the Number of Brakes in Railway Trains.

By Baron GOSTKOWSKI.

(Wochenschrift des österreichischen Ingenieur- und Architekten Vereines,
1887, p. 169.)

To attach a brake to every carriage in a train, the Author says, would be inexpedient, setting aside the question of cost, for the addition of a brake increases the weight of a carriage about half a ton; and as an empty goods truck weighs about 5 tons, the brake would increase its weight 10 per cent., and consequently the cost of transport would be proportionally increased. But the fixing of a brake to every carriage would produce an inequality in the conditions of safety, since slow trains would have an advantage over fast trains, as will be seen from the following formula deduced from experiments conducted by Mr. Weichert in Berlin:—

$$d = \frac{c^2}{3}.$$

where d = distance in metres in which a train with all the carriages braked can be stopped on a level, c = velocity in metres per second. Therefore for a velocity of 9 metres per second

$$d = \frac{9 \times 9}{3} = 27 \text{ metres,}$$

but if $c = 20$ metres, $d = \frac{20 \times 20}{3} = 133$ metres, or nearly five times the former. To equalise the two cases, therefore, it would suffice to attach brakes only to as many carriages of the slow train as would bring it to a standstill in 133 metres, and this is shown to be one-fifth of the number.

Hence it follows that only a fraction of the number of carriages in a train need be supplied with brakes, but what that fraction is will depend not only upon the velocity and the distance in which the train is to be stopped, but on the gradients of the line. The following Table has accordingly been compiled from the experiments of Negrelli, Schmid, Klinger, and others.

Gradient.	Pairs of Wheels requiring a Brake in	
	Passenger Trains.	Goods Trains.
1 in 500	$\frac{1}{8}$	$\frac{1}{12}$
1 „ 300	$\frac{1}{6}$	$\frac{1}{10}$
1 „ 200	$\frac{1}{5}$	$\frac{1}{8}$
1 „ 100	$\frac{1}{4}$	$\frac{1}{7}$
1 „ 60		$\frac{1}{6}$
1 „ 40	$\frac{1}{2}$	$\frac{1}{4}$

From the above Table it appears that in the case of a passenger train running on an incline of 1 in 100, one-fourth of the pairs of wheels require a brake. The accuracy of this Table was disputed by Mr. Tellkamp in 1874, who stated that it gave a greater number of brakes than were actually necessary, and that theory and practice would be brought more into harmony by referring the fractional values to the weight of the train, and not to the number of carriages requiring brakes. Accordingly, in a goods train running on a gradient of 1 in 200, one-eighth of its gross weight, and not one-eighth of the number of carriages, should be braked.

The Author however is opposed to this view, which he says is in contradiction to the physical laws regarding the conservation of energy, and he gives an illustration in support of his opinion, and remarks that the theory of brakes teaches that to obtain the

greatest possible brake-efficiency on a carriage weighing, say W tons, a pressure (D) must be exerted on the brake-blocks, so that $D = aW$, a being a coefficient independent of the weight W , to which he assigns the value $a = \frac{6}{5}$. Assuming that the action of the brake produces a friction of k kilograms for every ton weight of the carriage, then by exerting the pressure D , a friction $= Wk$ kilograms is obtained, which is the greatest possible; but if the pressure be less than D , the friction will be less, say $= Bk$, B being that portion of the whole weight which is available for brake-efficiency, so that $B = \left(\frac{D}{a}\right)$ tons.

In 1882 Chief Inspector Petrossi, of the Austro-Hungarian Railways, produced a formula for brake-efficiency in terms of the percentage of the weight of the train, the gradient per 1000, and the velocity, thus

$$z = m + \frac{c^2}{10},$$

where z = percentage of the weight of the train producing brake-efficiency, m = gradient per 1000, c = velocity in metres per second at the moment of applying the brake; and about the same time Mr. Klingl, Chief of the Administration of the Baden State Railways, submitted to the Technical Commission a more complex formula, which took into account both sliding and rolling friction; but it was rejected as not harmonizing with railway experience, and after many attempts to obtain such a formula, the general council of the German Railway Administration recommended the following unanimously :—

$$z = 5 + \frac{1}{f} \left[\frac{0.4 v^2}{600 - 1.5 v - 13 m} + \frac{m - w}{10} \right],$$

where z = percentage of weight of the train available for brake-efficiency, v = velocity in kilometres per hour, m = gradient per 1000, f and w = coefficients of friction; but even this was not accepted by many of the railway boards, because it did not harmonise with their practical experiences, nor is it approved by the Author, who concludes his Paper by stating that “between the weight of the braked carriage and its brake-weight, i.e., that portion of the weight which produces full brake-efficiency, there is generally a difference, and that in determining the number of brakes to be attached to railway trains, full allowance must be made for this.”

At the conclusion of the Paper, a discussion took place in which Mr. Rotter disputed the accuracy of the coefficient $a = \frac{6}{5}$ as the coefficient of friction between wheel and rails, and said that in unfavourable conditions of weather, it would fall far below that value. The Author in reply gives in detail a mathematical proof of the value of that coefficient, which he explains however to be not the coefficient of friction between

wheel and rails, but the relation between two frictions acting simultaneously, viz., the friction between wheel and rail, and the friction between brake-block and wheel, and is therefore independent of the weather.

W. H. E.

Snow-ploughs on the Railways of Denmark. By O. BURON.

(Revue Générale des Chemins de fer, August 1887, p. 115.)

There is a good service of snow-ploughs in Denmark. There are now ten ploughs, to be shortly increased to fourteen. They are constructed to traverse beds of snow five feet deep. There are ten standard types of snow-ploughs in use; that of Mr. F. Leemann, engineer of the Zealand system of railways, and that of Mr. Busse of the Jutland system. The ploughs are mounted on independent vehicles of timber, of which the back is a strongly framed inclosure, by which plate-iron armour is carried, presenting the appearance of two ploughshares symmetrically placed together, surmounted by overhanging spreaders, for the dispersion of the snow. The vehicle is carried on a four-wheel bogie at the fore part, and a pair of wheels at the back. The summit of the angle forming the bow of the plough, is notably in advance of the bogie in the Zealand vehicle, and is a little behind it in the Jutland vehicle. The leverage thus given in the first plough for the resistance of the snow, renders it necessary to ballast the vehicle—an expedient which is not demanded in the second plough.

The Zealand snow-plough weighs 9 tons, of which the bogie takes 5 tons, and the hind axle 4 tons. When loaded for service, it is ballasted with $7\frac{1}{2}$ tons of old rails, augmenting the gross weight to $16\frac{1}{2}$ tons, of which $6\frac{3}{4}$ tons are on the bogie and $9\frac{1}{2}$ tons on the axle. The bearing springs are very stiff. The plough is about $21\frac{1}{2}$ feet long, 10 feet wide, $8\frac{1}{2}$ feet high above the level of the rails. The point of the plough is 3 inches clear of the rails. It is fitted with buffers at the back, to take the pressure of the locomotive.

The Jutland snow-plough weighs $9\frac{1}{2}$ tons, of which 5·35 tons are on the bogie, and 4·15 tons on the hind axle. The vehicle is supported on the bogie by one spring, of which the flexibility is $\frac{1}{2}$ inch per ton of load. The hind springs have a flexibility of 0·6 inch per ton. The body of the plough is 19 feet long, $9\frac{1}{2}$ feet wide, $11\frac{1}{2}$ feet high above the level of the rails. These ploughs are light. It is considered that they are too high, and less stable than the Zealand snow-ploughs.

The snow-ploughs are, in general, propelled by one locomotive; occasionally by two. With the aid of these ploughs the Danish Railways are usually maintained open for service, even in times of violent snow-storms.

The Paper is accompanied by illustrations.

D. K. C.

The Mulhausen- Ensisheim-Wittenheim-Tramway.

By — NOACK-DOLLFUS.

(Bulletin de la Société Industrielle de Mulhouse, July-August, 1887, p. 232.)

In this communication Mr. Noack-Dollfus gives an account of this tramway, already constructed between Ensisheim and Mulhausen, and the practical results of the first year's operations. The ancient town of Ensisheim, situated on the Ill, in the valley of the Rhine, is $10\frac{1}{2}$ miles from Mulhausen, and $4\frac{1}{2}$ miles from Bollwiller, the nearest railway station. The works from Mulhausen to Ensisheim were commenced on the 18th of June, 1885, and completed on the 15th of December of the same year, in the course of one hundred and eighty days. Regular service was commenced on the 22nd of December. The line from Mulhausen to Wittenheim remains to be constructed. The cost of construction amounted to £18,541. The rolling-stock, consisting of two locomotives, eight passenger cars, thirteen goods wagons, cost £5,044; ground, £569; portions of lines belonging to the Mulhausen tramways, £1,130; miscellaneous charges, £575; total, including cost of construction, £25,859. On the length of the Mulhausen-Ensisheim line, exactly 10.29 miles, the total cost is at the rate of £2,513 per mile.

The working of the line is performed by the Mulhausen Tramways Company. The charge was based upon the costs for traction on secondary lines in Alsace-Lorraine, in 1884, namely:—

	Pence per Mile.
Strasbourg	14.94 (horse-traction)
Ribeauvillé	20.69 (steam-traction)
Mulhausen	20.49 (")
Luxembourg	19.54
Average (1.234 franc per kilometre)	18.91

The round number 1 mark per kilometre, equivalent to 19.16 pence per mile, was adopted as the basis of a contract for working the line. The actual cost to the Mulhausen Company was $17\frac{1}{4}$ pence per mile, leaving a net profit of £198. Three trains each way are run daily, with two special workmen's trains to Sausheim, and two supplementary trains on Sundays and holidays. All the ordinary trains are mixed, carrying both passengers and goods. The fares are reckoned at the rate of 1.34d. per mile for second class; and 0.96d. for third class.

The results of the year's working in 1886, show that there were—

Second-class passengers	8,111
Third " "	93,507
Workmen	89,750
Total	191,368

(say 527 persons per day). The comparative travelling habits of

the inhabitants are well indicated by a comparison of the population and the number of tickets issued, thus—

Localities.	Population.	Tickets issued.	Tickets per Inhabitant.
Mulhausen	64,000	145,255	2·27
Modenheim	80	819	10·34
Sausheim	1,334	15,034	11·27
Baldersheim	726	8,319	11·45
Battenheim	1,074	12,823	11·93
Ensisheim	3,206	8,018	2·50

Of merchandise there was conveyed 7,802½ tons, or 26 tons per day.

The mileage run by engines amounted to 31,402 miles. The receipts for the year were as follows :—

Passengers	£ 1,948
Workmen	199
Merchandise	911
Mails, &c.	9
	£3,067

equivalent to £298 per mile of line, or a little less than £6 per mile per week; or to 23·3d. per mile-run.

The gross expenses amounted to £2,195, or 71½ per cent. of the receipts; leaving £872 net revenue.

The way is laid to a gauge of 1 metre. The gradients are short and flat, rarely exceeding 1½ per cent. or 1 in 67. The way is laid on three systems: 1st. With ordinary grooved tram-rails in passing through villages, weighing 61 lbs. per yard; 2nd. Vignoles steel rails on wrought-iron longitudinal sleepers, laid wherever the width of the road does not attain to 23 feet from the centre of the road to the line of trees. The rail weighs 31½ lbs. per yard, and the sleepers 25 lbs. per yard. 3rd. Vignoles rails on cross-sleepers, for open spaces.

The locomotives are on Brown's system, from Winterthur. The cylinders are 8·66 inches in diameter, with a stroke of 13½ inches. There are four coupled 30-inch driving-wheels, and two pairs of wheels, one at each end, traversable on pivots. The fixed wheel-base is 1 metre, or 3·28 feet; the total wheel-base is 3 metres, or 9·84 feet. Each engine in working order weighs 14½ tons, of which there are 10 tons of driving-weight. The water-tank holds 444 gallons, and there is space for 8 cwt. of coke.

D. K. C.

Note on the Measurement of Velocities by the Gauging Tube.

By H. BAZIN.

(Annales des Ponts et Chaussées, vol. xiv., 1887, p. 195.)

In the experiments published in "*Recherches Hydrauliques*," the velocities were determined by a Darcy gauge. The velocities recorded are the means of several readings of the gauge, the object being at the time to determine the mean local velocities only. But the oscillation of height of the columns in the Darcy gauge is an index of the eddying agitation of the water. Mr. Bazin has now returned to the records of these observations, to examine whether they throw light on the amount and distribution of the eddying motions in the water. Generally four observations at each point were taken with the gauge, two with a maximum, and two with a minimum difference of height of columns. If h is the mean of these four observations, $v = \sqrt{2gh}$ was taken to be the mean local velocity at the point. Now let δh be the difference between the greatest and least of the four readings; δh is a function of the variation of velocity at the point due to the eddying motion. Bazin proceeds to examine the values of $\frac{1}{2} \frac{\delta h}{h}$ or of $\frac{g\delta h}{v^2}$, and also those of $\frac{g\delta h}{v}$. Taking any cross section of a stream, it may be divided into a central region where the greatest velocity is found, a lateral region near the sides, and two or three intermediate regions, in which the velocity is approximately constant. Bazin chooses three groups of experiments on rectangular channels of different roughness, each group containing three series of experiments on channels of different size. He tabulates the values of the quantities above for each region in these nine series of experiments. The quantity $\frac{g\delta h}{v}$ proves to be more constant than $\frac{g\delta h}{v^2}$.

Now consider the central region, and let Δ be the value of $\frac{g\delta h}{v}$ for that region. Let V be the maximum velocity and U the mean velocity in the cross section. Then Bazin finds the following relation to be satisfied for all the groups—

$$\Delta = M \left(\frac{V}{U} - 1 \right)$$

where $M = 0.36$ in these experiments. As to other regions of the cross-section $\frac{g\delta h}{v}$ increases from the centre to the sides, so that—

$$g \frac{\delta h}{v} = \Delta + N \frac{V - v}{U}$$

where N is 0.11 in these experiments. Bazin then examines whether similar relations hold in other groups of experiments on channels of different form, and in pipes. The ratio $\frac{M}{N}$ is found nearly constant and little different from 0.3 for open channels, but it is unity for pipes, thus indicating a difference in the nature of the movement in the channels and pipes already proved to exist in these researches. The quantity $\frac{g \delta h}{v}$ is nearly constant along a curve of equal velocity, but it varies in two channels of comparable dimensions in proportion to the coefficient which measures the roughness of the sides. Mr. Bazin, without attempting further theoretical interpretations, hopes that these results throw a ray of light into a region as yet unexplored.

W. C. U.

Experiments with Submerged Ajutages. By C. W. CLARK.

(Journal of the Association of Engineering Societies, 1887, p. 389.)

In this Paper, read before the Engineers' Club of St. Louis, Mr. C. W. Clark gives the results of one hundred and three experiments on the flow of water through submerged passages, limited to one form of orifice or mouthpiece, and four ajutages of various forms. Three of the ajutages were made in sections, in order that the length of each ajutage could be varied. The mouthpiece was of the form of the *vena contracta*, and was about $\frac{3}{8}$ inch in diameter. A hole was drilled through the side of each ajutage, near the junction with the mouthpiece, into which a small tube was inserted, connected by an india-rubber hose to one arm of a manometer, to the other arm of which another hose was connected, the end of which was submerged in the receiving-tank. The hoses being full of water, the diminution of pressure in the ajutage during the flow through it was measured by a column of mercury, which, reduced to its equivalent in water, gives the added head.

The first and second series of experiments were made to determine the coefficients of discharge through the mouthpiece in air and in water. The third series was made with an ajutage 6 inches in length, in three sections, 2 inches each, screwed together. The ajutage expanded to a diameter of $1\frac{3}{8}$ inch in the third section, and was thence contracted to $1\frac{1}{4}$ inch in diameter at the end. The fourth series was made with an ajutage 6 inches long, also in three sections. It expanded nearly uniformly to a diameter of $1\frac{3}{8}$ inch at the end of the second section, and thence in bell-mouth form to $1\frac{7}{8}$ inch in diameter at the end. The fifth series was made with a truly conical ajutage, 10 inches long, $2\frac{1}{4}$ inches in diameter at the end, in five sections screwed together. The sixth series was made with an ajutage of uniform diameter,

about $\frac{5}{16}$ inch, branched to form two quadrants diverging from the mouthpiece.

The coefficients of discharge computed from the data collected experimentally are given in the subjoined Table. The numbers of the sets of experiments signify the trial with one section, or two or more sections of the ajutages correspondingly.

No. of Experiment.	No. of Set.	Coefficient.
1. Mouthpiece in air .	..	0.952
2. " " water	..	0.945
3.	1	1.693
	2	1.790
	3	1.786
4.	1	1.518
	2	1.780
	3	1.865
5.	1	1.876
	2	2.026
	3	2.072
6.	4	2.086
	5	2.091
	..	1.382

The greatest coefficient here found is that of the conical ajutage in five sections. It is 2.2 times that of the simple mouthpiece submerged, and 3.4 times that of an orifice in a thin plate.

The manometer readings are investigated, and it is shown that the manometer recorded quite closely the difference of pressure on the outer and inner walls of the ajutages.

D. K. C.

*Irrigation in Egypt.*¹ By J. BAROIS.

(Ministère de l'Agriculture. Extrait du Bulletin de la Direction de l'Hydraulique Agricole, 1887, 23 plates.)

Few records have come down, and hardly any traces exist, of the system of irrigation practised in the time of the Pharaohs. The portion of Egypt capable of cultivation lies to the north of the first cataract at Assouan, from whence, to a few miles north of Cairo, the actual valley of the Nile is a narrow strip of land, about 560 miles long, with an average width of $7\frac{1}{2}$ to $8\frac{3}{4}$ miles; and the surveyed area of this portion, which is designated Upper Egypt, is about 3,890 square miles. Upper Egypt has a mean temperature of over 70° , and a mean annual rainfall of only 1.05 inch; so that its cultivation is entirely dependent on the Nile, fed by equatorial rains brought down by the Blue and White Niles which unite at Khartoom, and by the drainage of the

¹ Minutes of Proceedings Inst. C.E. vol. lxxxviii. p. 300.

northern slopes of the mountains of Abyssinia, discharged into the main river by the River Akbara a little south of Berber, beyond which point there are no affluents, though about 1,800 miles distant from the sea. The land around Assouan is about 310 feet, and at the point of the delta 56 feet above the mean sea-level of the Mediterranean; and the river flows in a bed scoured out through layers of alluvial deposit, whilst the land slopes slightly downwards from the river banks, towards the desert, to the extent of about 3 feet where the width of the valley, on each side, is from 3 to 4 miles. The exclusive supply of the Nile by periodic tropical rains accounts for the great regularity in the changes of the river, which always begins to rise in Egypt at the end of June, and continues rising till about the end of September, when it falls, at first rapidly, and then gradually, till the following June. The Blue Nile and the Akbara are the carriers of the silt to the Nile, which they bring from the table-lands of Abyssinia; and their somewhat torrential floods determine the period and the height of the maximum rise of the Nile in Egypt. The White Nile, being fed by the overflow of the large equatorial lakes, regulates the discharge; its waters cause the first rise of the Nile at Assouan at the end of June, about forty days after they have reached Khartoom, and maintain the height of the Nile after the floods of the Blue Nile and the Akbara have passed. At Assouan, the maximum flood almost always occurs between the 15th of August and the 1st of October; and from 1872 to 1881, the greatest difference in the lowest summer levels was $8\frac{1}{2}$ feet, and in the highest flood-levels 9 feet; whilst the mean rise of the river is about $26\frac{1}{4}$ feet. The mean velocity of flow above Cairo at low Nile is between $17\frac{3}{4}$ and $19\frac{3}{4}$ inches per second, and at the rise of the flood has been measured at $25\frac{1}{4}$ inches per second; whilst the discharge of the Nile at its lowest stage has been estimated at 16,250 cubic feet per second, and increases to 459,000 cubic feet during average floods. When Khartoom and Berber were in the possession of Egypt, observations on the gauges at those towns enabled timely warnings of the extent of the rise of the Nile to be transmitted to Assouan, so that the embankments could be strengthened, and other precautions adopted against exceptional floods; but now that the Egyptian control of the Nile terminates at Wady Halfa, only four to six days intervene between an observation of the flood-rise at that place, and its arrival at Assouan, from whence it reaches the point of the delta in nine to twelve days, so that it has become much more difficult to protect Egypt against high floods. The soil of the Nile valley in Upper Egypt, as well as in the delta, is composed of the alluvial deposits of the river, and these muddy deposits extend more than 33 feet below the river-bed, under which sands and gravels are found overlying beds of clay; and deep borings have shown that the alluvial deposits rest upon strata of marls, sandstones and schists. The soil of Egypt has been found by analyses to contain 45 per cent. of silica and 53 per cent. of clay; and, in general, it is mainly

composed of silica, alumina and oxide of iron, with small quantities of phosphoric acid, and not more than from 4 to 9 per cent. of organic matter; and a larger proportion of chloride of sodium is found on approaching the Mediterranean, attaining 4 per cent. in the middle of the delta. The substances contained in solution in the waters of the Nile do not differ materially from those found in many other rivers; but their relative proportions appear to vary according to the stage of the river. The quantity of matter carried in suspension varies greatly; every flood brings down water coloured red with the silt from the Abyssinian table-lands; but directly the top of the flood has passed, the quantity of silt diminishes rapidly, and the water regains its usual yellowish tint. Though generally the Nile mud contains but a small proportion of organic matter, yet during the first eight to fifteen days of rise the water has a greenish tint from the vegetable matter brought with the first flow from the vast equatorial marshes, and contains a large quantity of organic matter, but little silt. Each year the Nile brings down about 53 million tons, or 39 million cubic yards, of alluvium, of which half at least is conveyed during the two months of highest flood. The volume of matter annually discharged by the Rhone is two-thirds, by the Po one and a quarter, by the Danube twice, and by the Mississippi six times that carried in suspension by the Nile, so that the Nile is not a specially muddy river. The Nile mud contains on the average, at its high and low stages respectively, 55 and 58 per cent. of silica, 20 and 23 per cent. of alumina and oxide of iron, and 15 and 10 per cent. of organic matters, together with small quantities (from $\frac{1}{2}$ to 3 per cent.) of phosphoric acid, lime, magnesia, potash, soda, and carbonic acid. The alluvium of the Nile is rich in fertilizing matters, but is poor in lime, so that crops least requiring lime answer best in Egypt. Water obtained from wells, sunk at some distance from the river, contains four times the quantity of salts in solution found in the river water, consisting mainly of carbonates and sulphates of lime and magnesia, and chloride of sodium, collected in its passage through the soil. Wherever waters of infiltration reach the surface, a saline deposit is gradually formed by evaporation, rendering cultivation impossible, so that from dread of this result, the farmer often prefers to raise water from a lower level in the irrigation canal, rather than to receive the water at the level of the land.

At the beginning of the present century, Egypt was mainly irrigated by the inundation of large basins during the flood, affording only a winter crop; whilst only small portions of land adjoining the river, or otherwise conveniently situated, were irrigated for summer crops. Now, however, not only Lower Egypt, but also portions of Upper Egypt, are irrigated by canals in summer, so that the basin system is applied to less than a third of the whole land. Accordingly the summer level of the Nile is as important now as the flood rise; but this rise is still a subject of great interest, not merely for the lands cultivated by the old

system, but also because the flood waters are utilized to some extent on the irrigated lands, and when very high are liable to burst the banks and destroy the summer crops. Thus a flood rise above 66 feet on the Roda gauge, near Cairo, is dangerous, up to 62½ feet is good, up to 59 feet is poor, and below that level is bad. Thus in 1877, when the flood only reached 57 feet on the gauge, a famine followed, and the revenue was reduced two millions sterling, although, with summer crops, the country is much less dependent than formerly on the flood rise of the river.

The yearly inundations of the basins throughout Upper Egypt is systematically regulated. These basins are formed by an embankment, parallel to the Nile, high enough to protect them from direct flooding, and by transverse banks at the ends of each basin, either stretching to the neighbouring hills, or to the longitudinal embankment of another basin; and the basins are filled by one canal, and emptied by another, these canals following the line of the lowest ground. The water brought from the Nile into the first of a series of basins is distributed to the other basins by means of sluices, and, after remaining an adequate time, is discharged into the Nile through the drainage canal. The system of basins is much more extensive on the left bank of the Nile than on the right, where the valley is frequently barred by rocky projections, so that in many places, where the ground is rather high along the river, the land cannot be submerged except in years of high flood. The narrow strip of high ground along the left bank is also rarely submerged, so that its cultivation is mainly effected by irrigating it with water raised from the river. The success of the submersion of the basins mainly depends on the nature of the flood; if the flood is earlier than usual, it gets into the basins before some crops irrigated from wells have been gathered; if the flood is late, the sowing time is delayed, and the crops are exposed to the heat of the following spring; if the flood is low, a good deal of the land is too high to be submerged, or the water introduced is not sufficient, and cannot remain long enough to furnish a good harvest; if the flood is very high, the embankments are endangered; and if the flood lasts too long, the emptying of the basins is difficult and too slow. Generally the filling of the basins is commenced in the first half of August, and they are emptied during October. To obtain a good harvest, the waters should attain an average depth of 4½ feet, and remain sixty to seventy days on the land. During the dry season, the ground is split up by numberless cracks, so that it is thoroughly aerated; and this, combined with the deposit of mud from the river water, enables the farmer to sow with a mere raking of the surface on the moist soil. The inundation, moreover, besides irrigating and fertilizing the soil, removes the salts which tend to reach the surface by infiltration. Cereals usually alternate in the basins with crops of beans, lentils, or grasses; but where the supply of water is abundant, wheat can be grown several years in succession. Summer crops in Egypt can only be raised by irrigation; and the only important

irrigation canal in Upper Egypt is the Ibrahimieh Canal, constructed twenty years ago. This canal, starting at Siouk, borders the left bank of the Nile for a distance of 160 miles, and irrigates a strip of land averaging about $3\frac{3}{4}$ miles in width; and by supplying water to the natural branch channel, Bahr Youssef, it also serves for the irrigation of the province of Fayoom. The other lands in Upper Egypt, irrigated either by drawing water directly from the Nile or from small branch canals for summer crops, do not exceed 30,000 acres in area. If it was desired to extend to the whole of Upper Egypt the system of irrigation established in Lower Egypt, and to suppress the basins completely, a summer discharge of 12,350 cubic feet per second would be required for the total area of 5,000,000 acres of cultivated land, which would often exceed the summer flow of the Nile; so that it would be impossible to extend the irrigation for summer crops to the whole of Egypt without creating vast reservoirs to retain the flood waters.

After describing the irrigation works in Upper as well as in Lower Egypt, their methods of construction and maintenance, the Author gives an account of the primitive modes of raising water, which have of late years been supplemented by steam pumps, mainly centrifugal, of which there are now one hundred and forty, having a total force of 4,700 HP. A chapter is devoted to the crops grown, and the management of the irrigated land, and another to the benefits derived from irrigation; but these, and numerous other details, relating chiefly to Lower Egypt, are omitted from consideration here, as a Paper on Irrigation in Lower Egypt has been published in a recent volume of the "Minutes."¹ The reputation of Egypt for fertility is due rather to the contrast which the valley bordering the river presents to the neighbouring desert, and to the facility with which crops are raised under a rainless sky, rather than to any exceptional richness of soil. The Author considers that eventually irrigation will replace the basin system throughout Egypt, on account of the richer and more abundant crops which can be thereby raised; but special care will have to be devoted to the means of reducing the cost of removing deposits from the canals, particularly now that the employment of forced labour has been so greatly curtailed. The principal objects to be carried out in new works are: (1) The improvement of the existing irrigations, by rendering the summer discharge of the canals as independent as possible of low Nile level; by reducing the cost of maintenance; by raising the water-level nearer to the surface, and by regulating the drainage of the surplus water: (2) the introduction of irrigation on the land still cultivated by the basin system: and (3), the regulation of the flow of the Nile, so as to reduce the excessive floods, and increase the minimum summer flow. The first portion of this programme is in course of realization by the works commenced in 1886, which have for their object, as regards Upper Egypt, to flood with muddy water

¹ Minutes of Proceedings Inst. C.E. vol. lxxxviii. p. 300.

certain basins which at present only receive the clear water after the deposit has settled in previous basins; and, by means of siphons under the Ibrahimieh Canal, to supply muddy water in flood time to the basins beyond it, and to let off into the Nile, at the low stage, the water from the adjacent lands which, though capable of irrigation, are impregnated with salts from lack of drainage. The extension of the irrigation system to the whole of Upper Egypt is at present beyond the limited financial resources of the country; and though a scheme has been proposed by a French engineer for regulating the flow of the Nile by a gigantic reservoir in its valley, it is doubtful whether Egypt will ever be prosperous enough to admit of its realization.

L. V. H.

Canal from Lens to La Deûle. By — GRUSON and — BARBET.

(Annales des Ponts et Chaussées, vol. xiv., 1887, p. 25, 3 plates.)

Lens, a town of eleven thousand eight hundred inhabitants, and the capital of the coalfields of the Pas-de-Calais, has been connected with the system of navigable waterways by a canal, which passes near a great number of pits belonging to the Companies of Lens and of Courrières, the most important of the district, and serves the Liévin mines, which previously possessed no water-communication. The probable traffic on the canal has been estimated at 290,000 tons, with a prospect of future increase. The canal starts a little beyond Lens, and passes close to the town; and after a course of 4 miles 7 furlongs it joins the Souchez Canal at Harnes. This canal, about 2 miles 1 furlong in length, was constructed about 1862, and connects the Lens Canal with the Deûle Canal a little beyond Courrières. The total fall of the Lens Canal is 31 feet 10 inches, which is effected by three locks, the first with a fall of $8\frac{1}{4}$ feet, and the other two of 11 feet $9\frac{1}{2}$ inches. It has a bottom width of $17\frac{3}{4}$ feet in the straight portions, and in the curved portions the width at the bottom is regulated according to the formula $\left(17\frac{3}{4} + \frac{1,246}{R}\right)$ feet; and its depth is $7\frac{1}{2}$ feet, for an available draught of $6\frac{1}{2}$ feet. Crossing-places, 31 feet wide at the bottom and 360 feet long, have been formed about every 5 furlongs; and places for barges to wait in have been constructed, of the same width, at the commencement and end of the canal, 2,300 and 1,800 feet long respectively. Above the third lock, the canal traverses fissured chalk for a distance of 1,640 feet, and has accordingly been lined with concrete up to 1 foot above the water-level at a cost of £2 per yard; and where the canal passes over a marsh, filled up with stones from the pits, for about 330 feet, it has been cut off from the marsh by a puddle-trench carried down into a substratum of clay $13\frac{3}{4}$ feet below the water-level. The locks are of the ordinary type, 17 feet

wide, $126\frac{1}{2}$ feet available length, and $8\frac{1}{2}$ feet in depth, with sluices in the gates; and the gates have iron ribs and a wooden skin, and cost on the average £4 per square yard. The canal is fed by the River Souchez, only 620 feet from its commencement; and as the discharge of the river during the long drought of the summer of 1886 did not fall below 4.6 cubic feet per second, whilst the traffic on the canal would only require $2\frac{1}{2}$ cubic feet per second, allowing for losses from evaporation and leakage, it is evident that there is an ample supply for other purposes, and for increased demands for traffic. The canal was begun on the 1st of February, 1885, and was opened for traffic on the 30th of October, 1886. The works, including land, cost £74,000, or £15,206 per mile.

L. V. H.

The Locks of Saint-Aubin-Elbeuf. By H. HERSENT.

(Mémoires de la Société des Ingénieurs-civils, July 1887, p. 24.)

The Saint-Aubin locks are constructed in a deviation from the Seine above the Martot lock, rejoining the river opposite Elbeuf. Owing to the looseness of the soil, it was resolved to construct the Saint-Aubin locks by means of metal caissons and compressed-air.

The bottom having been dredged, the caissons were bedded on the ground, to form the side-walls and the sluice-chambers. The locks, two in number, are ranged side by side, having one wall in common between them. The larger basin is $521\frac{1}{2}$ feet in length, and $39\frac{1}{2}$ feet wide, capable of receiving at once a train of boats; the smaller basin is $193\frac{1}{2}$ feet long, 27 feet wide, to receive single boats. The lower sill is $6\frac{1}{2}$ feet below the level of the upper sill. The foundations were laid at a level 18 feet below the lower sill, reposing on a solid bed of compact white chalk.

The locks are quickly filled and emptied through flood-gates, fitted with metal Venetian blinds.

In constructing the locks, the work was divided into ten sections, for which ten caissons were provided and settled, in the following order: No. 1 caisson, left-hand wall of the smaller lock; No. 2, right-hand wall of the same, common with the left-hand wall of the larger lock; No. 3, lower gate-chamber of the smaller lock, with part of the left-hand wall of the larger lock; Nos. 4 and 5, remainder of the left wall of the larger lock; No. 6, lower gate-chambers of the same; Nos. 7, 8, 9, right-hand wall of the same; No. 10, upper gate-chambers of the same.

The ten caissons are $6\frac{1}{2}$ feet high for the working-chambers, and 5 feet higher for flotation and for the fixing of the dams; making together $11\frac{1}{2}$ feet, of plate-iron work merged in the mason-work. The wall caissons are $18\frac{1}{2}$ feet wide, and from 115 feet to 148 feet in length. The caissons for the gate-chambers are $134\frac{1}{2}$ feet by 72 feet. They were constructed on the ground and were slid into the water, on an inclined plane of 1 in 10, at low-tide.

For the construction of the masonry under the water-level,

movable iron dams, constructed of plate-iron stiffened with rolled joists, were employed, easily dismantled, and readily adaptable to all the caissons successively, though these were of various dimensions. They were bolted down to the caissons with india-rubber joints. The vertical joints between the caissons were satisfactorily made tight by the interposition of slips of wood of from $1\frac{1}{2}$ inch to 2 inches thick, between the metals, caulked with hemp. The joisting on the outside of the caissons was useful in fending off floating bodies from the plate-work.

When the caissons were brought separately to their places, and sunk with the masonry, the bottom was examined, with the aid of compressed-air, and cleared of the refuse of the dredgings, of which there was 3 feet in depth. It was taken out, partly with the aid of compressed-air syphons for the fluent portions, and air-valves for the solid *débris* and flint-stones. The lower edge of each caisson was sunk a little way into the sole and fixed there, in such a manner that the whole of the base was exactly seated on the solid ground. The caissons were then filled with concrete, which could be laid at the rate of 130 cubic yards per day.

The mortar was made with two pug-mills, driven by a steam-engine of 18 HP., by which a pump also was driven, for the supply of water. The compressed-air required for the caissons was supplied by four double-cylinder compressors, driven by ten steam-engines of 25 HP. each, by which was also driven a Gramme machine for electric lighting by means of four Jablochhoff candles. The excavations were lighted by means of glow-lamps, lighted by an electric current produced by two batteries of elements of supersaturated bichromate of potash, which was maintained with little difficulty. Since this experiment was made, in 1880, the employment of glow-lamps has become ordinary, but the electric current is produced by means of the Gramme machine.

For lifting stones, and loading wagons, a steam-crane was employed, on a line of rails laid to a gauge of $8\frac{1}{2}$ feet. It did good service for the classification of the rough stones, and the placement of the cut stones. A movable crane, on a truck, was employed on the caissons of the sluice-chambers. By means of floating shears, the parts of the dams and the large cut stones of from 10 tons to 15 tons weight, as well as the material for filling the caissons, were laid.

After the works were executed, an invert of concrete $6\frac{1}{2}$ feet thick was laid, to strengthen the walls and ensure a good foundation.

A remarkable occurrence took place after the work was finished. At the beginning of the winter of 1883-84, narrow vertical fissures were perceptible in the side-walls, to the right of some joints. Several bricks were broken across. The fissures were $\frac{1}{30}$ inch wide at the water-level, and they terminated at from 5 feet to $6\frac{1}{2}$ feet below the tops of the walls. It has been thought that these fissures arose out of the lowering of the temperature, and the contraction of the metal of the caissons.

D. K. C.

2 M

The Connection between the Heading-up due to Weirs and the Surface-Fall, according to Measurements in the Nile.

FR. KINDERMANN.

(Wochenschrift des Österreichischen Ingenieur- und Architekten Vereines,
1887, pp. 214-216.)

From time immemorial the height of the Nile has been registered at Rhoda on a "Nilometer," graduated into "pics" and "kirats" (1 pic = 24 kirats = 0·5404 metre), and by the readings on this gauge the admission of the water into the irrigation canals has been regulated.

In 1862, weirs were constructed in the river-bed at a point $18\frac{1}{2}$ miles below Rhoda, in order to head up the water when low, and enable it to be led off into the canals. The heading-up affected the reading on the Nilometer only to a trifling extent, until modifications of the weirs were made in 1884, which caused a rise of 2·24 metres (7 feet 4 inches), and materially affected the readings on the Rhoda gauge; but as these were recorded without making any allowance or correction for the heading up, there arose great confusion and error regarding the quantity of water available for irrigation. For example, in June 1886, the Nilometer at Rhoda registered 8 pics 6 kirats (about $14\frac{1}{2}$ feet), which is equivalent to a daily discharge of 67,294,902 cubic metres, and sufficient to irrigate 2,400,889 feddans (about $2\frac{1}{2}$ million acres), but deducting the rise of water due to the weirs, the true reading of the gauge would be 5 pics 4 kirats, or about 9 feet 2 inches, which represents a discharge of 6,620,573 cubic metres in twenty-four hours, or only sufficient for the irrigation of 236,449 feddans. Corrected readings on the Nilometer are therefore of the highest importance, and the problem for solution was to determine the natural surface fall, having given a series of readings at the weir and on the Nilometer, and bearing in mind that the readings on the two gauges do not always differ uniformly; that is, that high water-levels produce much greater surface-falls than low water-levels, as is shown in the following Table:—

	Nilometer.	Weir.	Total Fall.	Remarks.
	Metres.	Metres.	Metres.	
High-water levels. . . .	19·7883	17·5853	2·2030	N and B
Low- " " " " . . .	12·3803	11·3548	1·0255	n and b
Difference	7·4080	6·2305	1·1775	Difference.

From this Table $N - B = 2·2030$; $n - b = 1·0255$; $N - n = 7·4080$; $B - b = 6·2305$.

If the difference 1·1775 be distributed proportionally between the two gauges, there will be at the Nilometer—

$$\frac{(N - n) - (B - b)}{N - n} = \frac{1·1775}{7·4080} = 0·15895;$$

and at the weir—

$$\frac{(N-n)-(B-b)}{B-b} = \frac{1.1775}{6.2305} = 0.18899;$$

and therefore,

$$(N-n)-(B-b) = 0.15895 (N-n) = 0.18899 (B-b).$$

Now to find the fall P, or natural water-surface, if there were no heading-up.

As the differences in the water-levels diminish, the surface-falls will also diminish, till at last one is found where the excess = 0; and if the reading of this water-level be x , then $n-b = 0$; $N-B = 2.2030$; $(N-x)-(B-x) = 2.2030$.

$$\begin{aligned} \text{Hence } P &= (N-x) \frac{(N-n)-(B-b)}{N-n}; \\ &= (B-x) \frac{(N-n)-(B-b)}{B-b}; \end{aligned}$$

whence $x = 5.9286$, and therefore,

$$\begin{aligned} P &= (N-5.9286) \times 0.15895 \\ &= (B-5.9286) \times 0.18899. \end{aligned}$$

In this way the Author has constructed his scheme so as to deduce from a reading at the weir what the reading is on the Nilometer and *vice versa*, and also the total fall of the natural water surface, if there were no weir; and a Table is given showing the actual readings on the Nilometer as compared with the readings thereon deduced from the readings on the weir gauge. These observations extended from 1883 to 1885, and the results confirm the accuracy of the formulæ to a remarkable degree.

Calculations of the height and amplitude of the heading-up (as deduced from readings on the two gauges) are given in full in the Paper, as also the contraction at the overfall.

W. H. E.

*The Orédon Reservoir.*¹ By — MICHELIER.

(Annales des Ponts et Chaussées, vol. xiv., 1887, p. 326, 1 plate and 1 woodcut.)

The works for supplying the plain of Lannemezan, at the foot of the Pyrénées, and the numerous villages diverging from it, with water from the River Neste, consist of a canal starting from the river at Sarrancolin, and capable of discharging 280 cubic feet of water per second at the plain, from whence branch drains convey

¹ Minutes of Proceedings Inst. C.E. vol. lxxi. p. 402.

the water to each valley, and also of reservoirs for feeding the canal during the low stage of the river. The canal and the branch drains have been finished, and supply water from the Neste to the parched valleys, with great benefit to the inhabitants; and the Orédon reservoir is the first of the series which has been made, containing 9,508,000 cubic yards of water, out of the proposed total reservoir capacity of 30,085,000 cubic yards. It has been proposed to increase the capacity of the reservoir to 22,236,000 cubic yards, by raising the existing dam 62 feet. The lake of Orédon, which drains into the Neste, a tributary of the Garonne, is in a granitic region, and has an area of 59 acres. It is fed by the drainage from other lakes and some glaciers, and has been converted into a reservoir by a dam across its outlet, which enables its water-level to be raised $55\frac{1}{2}$ feet, and a cutting formed through its outlet enables its original water-level to be lowered 23 feet. The eleven cast-iron discharge-pipes, 1 foot in diameter, are laid in this cutting in two horizontal rows, and encased in a mass of Portland cement concrete, $26\frac{1}{2}$ feet thick and $16\frac{1}{2}$ feet high. The dam consists of an embankment, protected on its upper slope by a layer of concrete preserved from frost by dry-store pitching $3\frac{1}{2}$ feet thick. The site of the dam was stripped bare to the rock, and all loose pieces of rock were removed. The embankment was tipped from wagons running on rails from the place of excavation; it was consolidated by means of a stream of water, discharging about $3\frac{1}{2}$ gallons per second from a wooden pipe, $2\frac{1}{2}$ feet below the rails, with its outlet at the point where each wagon tipped its load, the pipe being lengthened as the embankment progressed. When two or three wagon loads had been tipped, the water was admitted into the pipe, whose orifice was buried in 4 to $6\frac{1}{2}$ cubic yards of earth; and the water, after penetrating the mass and rendering it pasty, found a vent, and washed earth, sand, and stones towards the base of the bank. The current was directed in various directions successively by men with iron hooks; and the water, flowing away to right or left in the trench, only carried off light soil and fine sand in suspension. The water soon drained from the mass, and left an absolutely incompressible embankment. The surface of the upper slope was then coated with a bed of concrete, 8 inches thick, upon which a layer of rubble stone, 1 foot thick, was placed, to serve as a drain for preventing any water penetrating the outer layer of concrete from reaching the bank; and the water reaching this drain passes into a collecting culvert built at the base of the rubble drain, through which the water flows to the discharge-pipes. The protecting layer of concrete, laid on the rubble drain, was coated on its outer surface with a $\frac{3}{4}$ -inch coat of bitumen, composed of 1 part of mineral tar, $1\frac{1}{2}$ of powdered theil lime, and 4 parts of fine baked sand, to form a watertight covering. This coat, though very solid and watertight at first, became less so after some lapse of time, and was therefore covered with a coat of 9 parts of tar and 8 parts of powdered lime, laid on hot. The surplus water of the reservoir flows over a waste-weir

131 feet long, the stream in flood time, with a full reservoir, reaching a height of $2\frac{1}{2}$ feet over the sill. The proposal to increase the storage by raising the dam was deemed too hazardous; but the only other way of obtaining the desired reservoir capacity would necessitate raising the water-level of some other lakes 36 and 40 feet, by dams as large as the Orédon dam, without the possibility of making an equally solid bank, through lack of suitable material.

L. V. H.

Bursting of the Stand-Pipe at Seneca Falls, U.S.

(The Engineering and Building Record, New York, Nov. 12, 1887.)

This tank, although not the highest, was said to have been of greater cubic contents than any in the United States. It was built of steel plates, the dimensions of the tower being 130 feet¹ above the masonry foundation, 30 feet in diameter at the base, tapering to 27 feet 9 inches at the top, giving a capacity of 630,000 gallons. The structure was in four rings, respectively 40, 35, 30, and 28 feet in height, the thickness of the material in the lowest ring being $\frac{5}{8}$ inch thick, in the second $\frac{1}{2}$ inch, in the third $\frac{3}{8}$ inch, and at the top $\frac{1}{4}$ inch. The tower was strengthened internally by three tee-bar hoops, 3 inches by 4 inches by $\frac{1}{4}$ inch thick, and stiffened at the top, which was uncovered, by a hoop of angle-bar 4 inches by $3\frac{1}{2}$ inches by $\frac{3}{8}$ inch. The base was formed of plates of two thicknesses, those joining the sides being $\frac{5}{8}$ inch, while those in the middle were $\frac{3}{8}$ inch thick. All rivets were $\frac{7}{8}$ inch in diameter, and spaced approximately $1\frac{1}{2}$ inch from the edge. The vertical seams were double-riveted, the rivet lines being 3 inches apart, and the pitch 3 inches. The horizontal seams were single-riveted, the pitch varying from 3 inches for the heavier sheets to $2\frac{1}{4}$ inches for the lighter. The weight of metal in the structure was about 270,000 lbs., and the weight sustained by the masonry when the pipe was full about 5,520,000 lbs., equivalent to a pressure of 8000 lbs. per square foot of foundation. The foundation was a circular pit 2 feet deep dug in the stiff clay soil. Into this, rough stone was dumped from carts and was raked approximately level by the masons, who then laid one course of stone in Rosendale cement to form the surface for bedding the bottom plates. According to the superintendent's statement, the structure was subject to no specifications, and was neither designed nor its erection superintended by an engineer. The tower was completed on the 1st of July, 1887, and was in constant use until the 28th of October following, when it burst with explosive force, many of the fragments being hurled to distances of from 100 to 150 feet from the base. An examination after the disaster showed that the plates were punched, and not reamed. The metal, when

¹ This should probably be 133 feet.

tested with chisel and file was fairly soft; but the fractures indicated a coarse poor description of steel, in all cases much under worked, and in some overheated and of unusual brittleness, with great lack of uniformity. The riveting was excellent. The burst shattered the lower 40 feet of the stand-pipe, hurling it in sixteen principal fragments in every direction; the upper portion, of about 90 feet, was projected nearly 30 feet clear of the base, and remained in one piece, considerably flattened. The plates, besides being torn apart at the laps, were greatly shattered, many of them broken across the corner or through the centre, rather more of them in a vertical than horizontal direction. Cracks and gashes extended from 6 inches to 4 feet into the body of the plates, from all lines of several rivet connections. The appearance of all cracks in plates was not of shearing but of sudden snapping. About seven-fifths of the rivets in laps that were torn open were not broken or sheared, and nearly all the plates except the bottom ones were torn through the rivet lines. A witness, who passed within 50 feet of the stand-pipe ten or fifteen minutes before its destruction, states that the water was then overflowing the top.

F. G. D.

On Canals for Supplying Water-Motors.

By ARTHUR THIRÉ, Professor at the School of Mines, Ouro Preto, Brazil.

(Annales des Mines, vol. xi. 1887, p. 132.)

Where artificial channels or flumes have to be constructed for conveying water for power purposes, there is often considerable uncertainty in determining the relative proportions and dimensions of the area and inclination of the channel, and the quantity and velocity of the water.

Let H = total height from source of supply to tail-race;

h = effective height of fall at end of channel;

l = length of the channel;

S = cross-section „

i = inclination „

Q = discharge „

v = mean velocity of the current.

Then $H = h + li$ (1)

and $Qh = Q(H - li)$ = effective motive force at disposal.

Also $Q = Sv$ (2)

and $i = m v^2$ (3)

where m is a coefficient depending on the section of the channel, and the nature of its walls or banks.

From (2) and (3) the available work will be found to be:—

$$Sv(H - lm v^2).$$

Then, v being the variable, the maximum:—

$$H = 3lm v^2;$$

or, from (3),

$$li = \frac{1}{3} H.$$

Now li is the height lost by the gradient or inclination of the channel. Consequently; *of all channels of a given length and section, that which supplies the greatest motive-power at its extremity is the one whose inclination is equal to one-third of the total fall, leaving two-thirds of the height available for motive purposes.*

Remarks. (1) The above only applies to cases where part only of the water is taken off by the canal. If the whole stream is diverted, the gradient should be limited to that strictly necessary, so as to utilise the greatest possible height of fall.

(2) The gradient must of course be limited by the velocity which the banks of the canal can stand without damage.

(3) In practice, the gradient would not be constant throughout. In parts where the construction is difficult and expensive, a greater fall and smaller cross-section would be adopted, and *vice versa*; but the above rule, without being mathematically correct, will furnish a useful guide for the mean average gradient.

W. S. H.

Analysis of a Hydraulic Step. By Prof. F. G. HESSE.

(Bulletin of the Department of Mechanical Engineering, University of California, 1887.)

In some irrigating-machinery a vertical shaft, supporting a heavy load, required to be supported by a footstep under water. Lubrication, except with water, was impossible, and as the water contained a large amount of grit, a lignum vitæ pivot seemed not likely to be durable. Girard's method of forcing water under the step was too complicated.

It occurred to the Author that a permanent supporting upward pressure might be created by the agency of a forced vortex maintained by the rotation of the shaft itself. The footstep designed consists of a cylindrical vessel divided by diaphragms. Through this the shaft passes to a small footstep at the bottom. A disk attached to the shaft is in each chamber formed by the diaphragms, and the disk carries on its upper side radial vanes. Stationary vanes are on the diaphragms below each disk. When the shaft rotates, a forced vortex is created on the upper side of each disk, while on the under side the pressure in the water, stilled by the stationary vanes, is uniform and equal to the pressure at ^{the}...

circumference of the forced vortex. Consequently there is a resultant upward pressure supporting the load on the shaft.

Very careful experiments were made on the supporting pressure and on the frictional waste of work in the footstep. The supporting upward pressure was found to be 0.95 of the theoretical pressure due to a forced vortex above and still water below the disks, and the friction was found to be much less than that of a well-lubricated ordinary footstep or collar-bearing with the same load.

The Author arrived by experiment at the following equations:—

d = diameter of disks in inches;

m = number of disks;

n = rotations per minute;

λ = a constant varying from 0.000006 for a 6-inch disk, to 0.000005 for a 12-inch disk.

Supporting force in lbs.

$$= P = 0.001 d^4 n^2 m.$$

Work lost in friction in foot-lbs. per second

$$= L = 0.1047 n^3 \lambda d^5 m.$$

W. C. U.

The Drainage of Charlottenburg. By — KÖHN (State Architect).

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, 1887, p. 577.)

The Author describes the state of the town before any sewerage work was undertaken, and explains the various steps which entailed the necessity for a complete scheme of sewerage; this was prepared in 1873. The estimated cost of this first project was 145,624 marks (£7,281), but it was not carried out in consequence of the expense which was deemed excessive. Subsequently when Berlin declared in favour of water-carriage and radial systems of sewerage, it was proposed to unite with Berlin and to adopt a joint system, but this plan was negatived in 1876. While these negotiations were in progress a sewerage scheme, submitted by Messrs. A. Aird in December 1875, was considered, and though nothing much was done, it was not given up until 1877. Sundry regulations as to the use of cesspools and decrees against the admission of water-closet matter in the house-drains were enacted in 1877, and in the following years it appeared as if the inhabitants had no alternative but to make use of a tub system. Great outcry arose later from the owners of property in the better parts of the town, who wished to build houses of the same type as those in Berlin, and who affirmed that they would be unable to let their houses if a tub system were enforced. In the meanwhile a fresh sewerage scheme had been prepared in which the town was divided into

three districts. This plan entailed an estimated expenditure of 2,262,000 marks (£113,100), but the scheme was reported upon unfavourably. The sewerage difficulty became more and more pressing, and in February 1883, the municipal authorities decided to make trial of the Liernur system. All this time in spite of magisterial enactments the use of water-closets was on the increase, and householders were availing themselves of the house-drains for the discharge of the closet contents. Subsequent inquiries were directed by the authorities into the working of Lindley's tank treatment at Frankfurt, and into the processes carried on by Dr. Petri at Plotzensee and Marienfeld. Plans were actually prepared for a precipitation process entailing a pumping-engine and outfall works, the cost of which was estimated at 450,000 marks (£22,500), but this scheme was laid aside. In the autumn of 1884 some of the members of the Town Council went as a deputation to Wiesbaden, Carlsruhe, Augsburg and other large towns in Southern Germany, to examine into the working of the dry-system in general use and details are given of the mode of dealing with the excreta in each town. The opinion was adverse to the introduction of any of these plans for reasons indicated by the Author. The Liernur system, as also that of Shone, are discussed in detail, and it is shown that there were insuperable objections to the employment of a pneumatic system. In November, 1885, an arrangement was made under which the southern quarter of the town was united with the seventh radial district of the Berlin sewerage system, for a first payment of 50 marks and an annual charge of 6 marks per lineal metre of street frontage connected with the sewers. A large portion of the south-east quarter of the town has already been sewerred in accordance with this arrangement, and the Author was commissioned to prepare a scheme for the sewerage of the rest of the town on the water-carriage system. His plans, based upon those of Hobrecht, embrace an area of 720 hectares, and involve the construction of 120,815 metres of drains at an estimated expenditure of $7\frac{1}{2}$ millions of marks (£375,000), exclusive of rising main and irrigation works.

G. R. R.

The Effluent from the Berlin Sewage-Irrigation Works and its Effect upon the Water into which it is conveyed.

By Prof. ALEXANDER MÜLLER, of Berlin.

(Gesundheits-Ingenieur, 1887, p. 529.)

Many difficulties have been caused, and lawsuits have arisen, owing to alleged pollution of rivers by sewage-effluents, as no one can legally be compelled to receive on to his land the water conveyed in the first instance by artificial means to the property of his neighbour. Various instances of such litigation are quoted in

connection with the sewage-treatment at Dantzic and Berlin. It is obvious that the extent of such pollution of watercourses by sewage-effluents, and of the damage thereby occasioned, is often very difficult to define. The Author states that an interesting example of a lawsuit of this character is furnished by the attempt of the landowner, in whose property is situated the Teltower See (a small lake), to establish a case for damages against the City of Berlin for polluting the lake by the effluent water from the irrigation works of Osdorf and Heinersdorf, which receive the sewage from the southern districts of Berlin. The Author was engaged with other experts to investigate this question, and his report is now published in order that his opinions may be critically examined by the profession. The facts which need to be ascertained are whether by means of the clarification which it is possible to obtain in the passage of the sewage through land, an effluent would be produced which would have no injurious effect either from the chemical, or from the sanitary point of view, on the waters of the lake; and further it is necessary to form an estimate of the volume of such effluent; as it is clear that the extent of the damage would depend upon the product of these two factors, quality and quantity, when the amount of impurities in a given volume has been established. No actual figures have been settled which indicate the amount of sewage-water annually treated on the works of Heinersdorf and Osdorf, but the area under irrigation is set down at 112 hectares, with a possible future extension amounting to 82.70 hectares. The approximate total volume of sewage-water dealt with per diem, taken from the published statements of the Berlin authorities, is $3\frac{1}{2}$ liters per square metre, which would give an annual volume of about 12,000 cubic metres per hectare; and this may be regarded as a fair average for the whole area, however much the daily volume over certain portions of the 112 hectares may fluctuate. According to the estimate of the engineer, only one-third of this volume passes away as an effluent, one-third is evaporated from the surface of the land, and the remaining third is wholly absorbed. The Author explains that he cannot accept this statement, which is not founded upon any accurate observations, and he supplies grounds for its rejection. Basing his computations upon the amount of dissolved chlorine found in the effluent water from irrigation-works, he argues that no great diminution of volume in the effluent as compared with the amount of the raw sewage pumped on to the land can be assumed. Even if it could be established that only one-third of the water used in irrigation issued from the subsoil drains, the whereabouts of the remaining two-thirds would have to be proved, and as a matter of fact, the areas under irrigation have in many cases become waterlogged, and the water-level in the soil has risen in some places as much as 20 feet since the works were started. He assumes that about two-thirds of the volume of sewage passes away from the land, or not less than 2 liters per square metre, or 2,240 cubic metres daily from the present area, liable to future increase to

3,894 cubic metres per diem, when the whole extent of the property is under irrigation. Taking 3000 cubic metres, however, as the volume in round figures, he states that this quantity of water would very considerably swell the dimensions of the Besinggraben (the watercourse which receives the subsoil drainage), and would seriously affect the character of the Teltower See, from which the effluent differs greatly in composition and quality.

The conditions under which irrigation is possible are next examined, and it is shown that during nearly six months in each year no vegetable growth takes place on the land, and the sewage constituents are useless to vegetation. During part of this time the land acts only mechanically as a filter-bed, and in frosty weather, it is even necessary to store up the liquid in reservoirs. The valuable nitrates formed in the soil are for the most part lost and pass away in the effluent, while in soaking through the land the superabundant water washes out the soluble lime and magnesia, the common salt passing out unchanged. It is a known fact that whenever a local water-supply is rich in lime, potash, and sodium chloride, with abundant traces of nitrates and phosphoric acid, some previous pollution is diagnosed. Such impure water speedily attracts a rich growth of vegetable organisms, and, however desirable this liquid may be from an agricultural point of view, it is extremely objectionable when it is destined for household use, for the supply of ice, for bathing, or simply for ornamental purposes. The nature of the growths of weed, &c., which speedily arise in polluted water, and the kind of mud produced, are discussed, and an estimate is given of the vast quantities of manurial substances annually conveyed into the lake. The area of the lake is 60 hectares, and the Author maintains that sufficient nitric acid is carried into it each year to manure a corresponding area of land sixteen times over. After setting forth the foregoing facts in a series of conclusions, the Author summarizes the matter in the following terms:—

1. (a) The water that has been called in question, after it has served the purposes of irrigation, and has been deprived, in its passage through the soil, of the whole of its solid suspended matter, and a great part of its dissolved impurities, has, when it reaches the Besinggraben on its way to the Teltower See, no longer the nature of sewage, unless in consequence of carelessness in conducting the irrigation-works, certain quantities of the raw liquid should find their way to the river without passing through the land.

(b) When the operations are duly conducted the effluent into the Besinggraben, or the subsoil water passing direct into the lake, is tolerably free from ammonia, and therefore contains but little fecal and excrementitious matter; on the other hand, it is rich in nitrogen compounds and lime, and contains also relatively large quantities of potash and phosphoric acid.

2. Owing to the influx of this effluent water, which differs little

in volume from that of the untreated sewage, into the Teltower See, the water of the latter, in consequence of the luxuriant vegetable growth thereby promoted, becomes considerably changed, and the lake becomes, consequently, more and more injured for drinking, washing, and bathing purposes, the longer the influx continues; and this is the case even though no actual inflow of raw sewage should accidentally take place.

G. R. R.

The Present State of Sewage-Purification. By Dr. J. KÖNIG,
of Munster.

(International Congress for Hygiene, Vienna. Gesundheits-Ingenieur, 1887, p. 651.)

The laws prohibiting the pollution of rivers in different European countries are briefly discussed, and the various systems of excrement-removal are considered:—(a) *Cartage-systems*.—The tubs employed for the collection of excreta have in general been made air-tight. Under the cesspool system, the great evil undoubtedly is that the receptacles are pervious, and thus the soil beneath the dwellings becomes increasingly polluted.

Langsdorff has shown that, in 1882, Dresden, with a population of two hundred thousand inhabitants, yielded a total of only 50,342 cubic metres, instead of the normal volume of 100,000 cubic metres of dejections, thus fully half the excreta soaked into the soil. The tub system, where properly managed, is much to be preferred to cesspools. The cost of removing 1 cubic metre of cesspool-matter varied from 1·15 mark to 4·90 marks; the removal of 1 cubic metre in tubs cost from 2 marks to 2·12 marks; in Kiel, where the scavenging is undertaken by the municipal authorities, the cost was 1·40 mark per head per annum. An account of the various substances used for the disinfection of midden contents follows, with valuations of the different products. Poudrette, made from excreta at Augsburg by v. Podewils, contained 5 per cent. of nitrogen, $9\frac{1}{2}$ per cent. of phosphoric acid, and 2 per cent. of potash. The systems of Shone, Breyer, and Liernur-Berlier have not yet been carried out in Germany, but the latter plan is spoken of in terms of praise.

(b) *Irrigation*.—Berlin, Breslau, and Dantsic have adopted the principle of water-carriage; Hamburg, Altona, Frankfort-on-the-Main, and Bunzlau, have likewise employed this system, but the Hanse Towns discharge their raw sewage into the Elbe. Tanks have been constructed at Frankfort for precipitating the sewage; and at Bunzlau the water, after simple subsidence, is used for irrigation. Analyses are given of the sewage-water of Berlin and Breslau, before and after its use in irrigation, and the conditions under which sewage-water can be successfully applied to land are formulated. (c) *Filtration of sewage-water*.—Filtration through sand,

charcoal, slag, peat, &c., has not proved satisfactory on a large scale in England. (d) *Precipitation by means of chemicals*.—Precipitation with chloride of manganese, or lime and sulphate of alumina. These chemical processes seem more adapted for the waste-water from factories. All precipitants fail to remove the nitrogen, and only arrest temporarily the process of putrefaction. (e) *Purification by mechanical means*.—In these cases the plans proposed at various times have mostly fallen into disuse. Special reference is made to the Rockner-Rothe¹ process, the working of which is described. The Author deprecates unnecessary stringency as respects the degree of purity to be attained in the treatment of polluted liquids before their discharge into running-water.

G. R. R.

On the Influence of Lime and other Minerals on the Dry Distillation of Coal.

By Dr. KNUBLAUCH, Chemist to the Cologne Gas- and Waterworks.

(Journal für Gasbeleuchtung, 1887, p. 55.)

Numerous inquiries have been made into the effect upon the ammonia and sulphuretted hydrogen obtained by the addition of lime to coal in gas-making. Opinions upon this differ, owing probably to the impossibility, with ordinary working, of determining small variations in the yields of the various products, and also to the varying temperatures of the retorts. With experimental apparatus, these irregularities may be avoided, and the following results were arrived at with experiments so made.

The proportion of the nitrogen in the coal that is converted into ammonia is very variable; with Westphalian Coal it amounts to only about 12 per cent. of the total nitrogen in the coal. As ammonia is formed by heating nitrogenous matter with quick lime some increased formation of ammonia might be expected from the addition of lime to the coal. On the other hand, this depends upon whether the particles of nitrogenous matter are surrounded by lime, or whether the particles of lime are surrounded by the organic substances. The lime may also be acted upon by the sulphuretted hydrogen, but to what extent can only be determined by experiment.

To ascertain whether other materials besides lime affect the process of distillation, similar samples of coal were mixed with 5 per cent. of silica, a body to which no chemical reaction could be attributed, and, notwithstanding the small proportion added, an important difference was found in some of the products.

The following Table shows the differences in the yield of the

¹ Minutes of Proceedings Inst. C.E. vol. lxxxv. p. 466.

products from 1000 kilograms (about one ton) of coal, with the addition of varying proportions of lime and silica:—

1000 Kilograms Coal.	Lime.		Silica.	
	Additions.			
	2½ per cent.	5 per cent.	10 per cent.	5 per cent.
Gas cubic feet increase	519	710	1,246	760
Coke per cent. increase	16·8	18·2	17·5	27·4
Tar „ decrease	5·2	7·9	9·0	11·8
Ammonia „ increase	0·483	0·608	0·929	0·15
Sulphate of ammonia „ „	2·02	2·53	3·88	0·67
Sulphuretted hydrogen „ decrease	1·42	1·58	1·81	0·21

According to the above, the variations in the products do not bear any proportion to the quantities of lime or silica added. The yield of gas follows the additions more closely than the other products, but, on the contrary, with lime the ammonia increases very slowly, and the decrease in the sulphuretted hydrogen is still more gradual; it is also not certain that greater variations may not be produced with the addition of less than 2½ per cent. of lime. Silica has no influence on the ammonia or sulphuretted hydrogen, as no chemical action takes place. The decrease in the yield of tar with the increase in the gas and coke are interesting, as the increase of coke is considerably greater than the decrease of tar, and consequently more carbon has passed off. As, however, more gas is produced, there must be a smaller proportion of carbon in the gas, and its increased volume must be largely due to more hydrogen.

The effects of the addition of 2½ per cent. of lime to the coal may be summarised as follows:—1. The yield of gas is increased by 5 per cent., but the illuminating power is decreased more than 5 per cent. 2. The coke is increased 4 per cent., of which 2½ per cent. consists of the added lime, so that the actual gain of coke is only 1½ per cent., and the calorific value of the increased quantity is about the same as that obtained without lime, as the ash is increased 3½ per cent., and the combustion is imperfect. The sulphur in the coke is also increased 0·20 per cent. 3. The quantity of the tar is decreased 10 per cent., and the quality is likewise lower. 4. The ammonia is increased. 5. The sulphuretted hydrogen is slightly decreased, and more is retained by the scrubbers and washers, by the increased quantity of ammonia. 6. The carbonic acid in the crude gas is increased 10 per cent. 7. The cyanides are somewhat decreased, but this has no direct influence on the formation of the ferro-cyanides. Further proof is still needed, as to the influence of the lime upon the sulphur compounds, other than sulphuretted hydrogen, in the purified gas.

C. G.

Results of Experiments on the Construction and Working of Retort-Furnaces.

By G. LIEGEL, Manager of Gasworks, Stralsund.

(Journal de l'Eclairage au Gaz, 1887, p. 9.)

It is well known that by diminishing the pressure in the retorts more and better gas is obtained. This pressure is caused by the seal of the dip pipes in the hydraulic main and by the passage of the gas through the apparatus. A series of experiments made with and without the hydraulic main seal gave an increase of 5.56 per cent. in the yield of gas with no pressure in the hydraulic main as compared with a pressure of 5.5 inches.

The Author recommends the hydraulic main to be fixed upon columns in front of the retort benches, the ends of the dip pipes to be bent and with 1.18 inch seal, the mouth-pieces of the retorts being supported either from the ground or from each other, thus rendering the fittings independent of the contraction and expansion of the retort benches. The thickening of the tar in the hydraulic main is a serious inconvenience, due to its containing too small a proportion of the heavy oils; to increase these, the volatile products of distillation should only be heated sufficiently not to diminish the yield of gas, and, as it is not possible to entirely prevent deposits of pitch, its formation should be encouraged in positions from which it can be easily removed. To prevent the volatile products being over-heated, the coal should be in even layers in the retorts. Flat bottomed retorts are preferable to elliptical ones, because in the latter the coal is over-heated at the sides while the middle portion still contains gas. The gas, as generated, should also be speedily removed from the retorts, so that it may not become over-heated; and, to assist this, the space in the retort above the coal should not be too large. $\square$ -shaped retorts are recommended, 9 feet 10 inches long, 25 inches wide and $13\frac{3}{4}$ inches high. In order that the pitch may be deposited before reaching the hydraulic main, the gas should be cooled as much as possible before arriving there, and, to effect this, the front wall of retort bench should be thick, the mouth-pieces should project considerably, and the ascension pipes be kept as far forward as possible, the latter being of sheet iron and of large diameter. With retort benches constructed on these principles and worked with Levenson Wallsend coal, the yield of gas per retort was 9,182 cubic feet per twenty-four hours. The seal of the dip pipes was 1.18 inch, and the pressures in the hydraulic main varied from 1 inch to $2\frac{3}{4}$ inches at various periods of each charge.

The economy of fuel with regenerative furnaces over ordinary furnaces is due to the possibility of admitting only sufficient air for perfect combustion, while ordinary furnaces always work with a large excess of air; and also to the secondary air-supply being heated by the waste heat. To determine the advantages due to each of these, a bench of retorts was erected, so that it could be

worked either with cold or hot air, and the following results were obtained per ton of coal carbonized :—

	Cubic Feet of Gas.	Coke for Fuel. Lbs.	Breeze. Lbs.
With heated air . . .	10,330	219·5 +	134·1
Without „ . . .	9,627	219·5 +	134·1
„ „ . . .	10,330	255·8 +	152·3

so that with an equal consumption of fuel the yield of gas was increased 7·3 per cent. by heating the air, or to obtain an equal yield of gas without heated air, 15·2 per cent. more fuel was required. Taking the calorific effect obtained from breeze to be two-thirds that of large coke, the quantity of large coke alone required for the furnace would have been—

without heated air, 15·95 per cent.
with „ „ 13·78 „ „

assuming the average consumption of coke in ordinary furnaces to be 24 per cent., the economy realised by the combined use of gaseous fuel and heated air is 228·8 lbs. of coke per ton of coal carbonized, of which the gaseous fuel will save 78·77 per cent. and the heated air 21·23 per cent.

The furnace had six air-channels on each side for heating the secondary air-supply; and, to ascertain whether a smaller number of channels would be sufficient, four of these on each side were stopped, and the secondary air passed only through the two last, the result being that the two channels on each side were found to give equally good returns.

The average of three trials, each of three days' duration, were :—Gas per retort per 24 hours, 5,686 cubic feet; gas per ton of coal carbonized, 10,847 cubic feet; fuel used per ton, 403 lbs. coke, or 269 lbs. coke and 151 lbs. breeze.

C. G.

On a Proper Estimate of the Value of Water-Gas. By G. LUNGE.

(Oesterreichische Zeitschrift für Berg und Hüttenwesen, xxxv., p. 444 (Chemiker Zeitung, No. 51, 1887).)

According to the Author, Naumann's estimate of the calorific value of water-gas, which on theoretical grounds is considered to stand to that of ordinary producer-gas in the proportion of 92 or even 100 to 79·5, is entirely incorrect. The term water-gas is indifferently applied to two very dissimilar substances. Properly speaking it should be restricted to the mixture of theoretically equal volumes of carbonic oxide and hydrogen, obtained by the action of steam upon ignited coal at a sufficiently high temperature. Very usually, however, the same term is applied to the gas of Wilson's, Dowson's, and the newer forms of Siemens producers, when water

or steam is introduced, and which contains at most 10 to 15 per cent. of hydrogen. This product, which Lunge distinguishes by the name of "semi-water-gas," differs but little from ordinary producer-gas, and on the most favourable conditions may realize a small advantage by utilizing heat that would otherwise be lost by radiation; but in practice the chief value of water or steam so applied is in preventing the formation of slags, and so facilitating the removal of the ash of the fuel. As regards water-gas proper, even a purely theoretical consideration leads to the conclusion that in its production, the heating power of the fuel is not utilized to the greatest advantage. The only material with which it can be rightly compared is ordinary producer-gas. The production of the latter, however, signifies nothing more than the combustion of carbon to carbonic acid by two stages, namely: $C + O$ to CO , and $CO + O$ to CO_2 , which has the important advantage over the direct combustion of carbon to carbonic acid, of not requiring a great excess of air, as it may be effected with very little above the theoretical quantity, and not more than that required for water-gas. Naumann considers that the heat produced in the first stage (C to CO) is entirely lost, but this would only be true on the supposition which has not yet arisen in practice, that the gas produced at a central station is cooled down to the temperature of the air in order to supply it through pipes to consumers at a distance. As a matter of fact, producer-gas has, up to the present time, been generally delivered hot to the furnace, so that theoretical calculations of the heating-power should be based not on the 68,370 calories of CO to CO_2 , but on the 96,960 calories of complete combustion. Another point that must not be left out of consideration, is, that water is introduced into the process in the liquid form, but leaves it in the chimney gases as steam, which gives rise to an unavoidable loss of heat of 8 per cent. A further disadvantage in the products of combustion of water-gas which has been previously noticed by Winkler, is the presence of two volumes of steam, in addition to two volumes of carbonic acid and eight volumes of nitrogen, or $16\frac{2}{3}$ per cent. of the whole, so that the heat carried away by the chimney gases is one-fifth more than that experienced in the combustion of producer-gas for the same volume of air consumed. From these facts it follows, that apart from the greater complication of the method, in the production of water-gas the calorific power of the fuel is less perfectly utilized than in the ordinary gas-producer, and the results obtained in practice entirely bear out this conclusion. On the basis of the heat results obtained with the most improved water-gas apparatus at Essen, Lunge considers that this loss is about 16 per cent. higher than that experienced in the ordinary producer.

In spite of this result, however, it appears certain that there is a large field open to the use of water-gas, mainly on account of the exceedingly high temperature which it is susceptible of producing with very simple appliances. This seems to the Author to be due to the small size of the flame. Water-gas burns much

more rapidly than either that of producers or gas-retorts, the surface of the flame being only one-sixth of the size of that of a coal-gas flame consuming an equal quantity of gas, and therefore the loss of temperature by radiation is proportionally less.

The most hopeful application of water-gas seems to be for illuminating purposes by the Fahnejelm magnesia comb. This when new gives, with a consumption of 150 litres of gas per hour, a light of from twenty to twenty-two candle-power, diminishing gradually to fifteen candles, or that of average coal-gas, in about fifty hours, and requires renewal after sixty hours' work. The cost of the comb being 1.2d., corresponding to 0.132d. per cubic metre of gas, that of the light, at a maximum price of 0.84d., is only increased to 0.96d. per cubic metre (about 33d. per 1,000 cubic feet). This is not only considerably cheaper than that of ordinary lighting gas, but the light is more brilliant and the products of combustion are less deleterious than those of coal-gas. Auer's incandescent light is not considered by the Author as likely to be a serious competitor to the magnesia light, as the incandescent substance is very unequal in quality, and will not support the smallest current of air, so that in its present form it seems to be totally unfitted for ordinary house and street lighting.

As water-gas contains more than 40 per cent. of carbonic acid, it is about five times as poisonous as coal-gas, and it would be desirable, therefore, before its general introduction for domestic service, to devise means of imparting to it something of the familiar penetrating odour of the latter, in order that even a small leakage might be readily ascertained.

Further applications of water-gas may certainly be anticipated for domestic heating and cooking purposes, for which however it would be required in larger quantity than coal-gas, the absolute heating power of the latter being nearly twice that of the former. According to Blass the consumption of a water-gas stove for heating rooms is 0.01 cubic metre per cubic metre of space warmed per hour. Another application is in driving gas-engines, for which purpose the consumption is, according to trials made at Essen, 2 cubic metres per HP. per hour.

H. B.

The Castle Engine.

(American Machinist, 1887, p. 7.)

The above article contains a description of a high-speed engine which has some novel features. The engine is of the type of those in which the piston forms its own slide-valve, but in the present case a cut-off and lead are obtained.

The engine is vertical and single-acting, and has a trunk piston. The crank is in the centre of the shaft, with a bearing on each

side, but the crank-pin is not parallel to the axis of the shaft, being inclined at a considerable angle. The connecting-rod end has what in effect is a universal joint, where it is coupled to the crank-pin brass.

As the crank revolves, the piston moves up and down, but at the same time receives a twist, and the amount of this oscillation depends on the angularity of the crank. The piston has ports and passages cast in it, and the oscillatory movement is used to obtain the admission, cut-off, and exhaust.

It is claimed that the engine is economical, and has few parts.

W. P.

Evaporative Trial of an Oval Boiler with Two Flues.

(Zeitschrift des Verbandes der Dampfkessel- Ueberwachungs-Vereine, 1887, p. 89.)

The Lancashire type of boiler is deservedly in great favour for industrial purposes; but owing to the increasing thickness of the plates for large diameters and high pressures, the area of heating-surface which can be attained with this system, is practically limited; for a diameter of shell greater than about 7 feet 3 inches, the gain in heating-surface soon bears a very unfavourable proportion to the corresponding increase in weight, while the efficiency of the former is diminished. These considerations led to the construction by Messrs. Främb and Freudenberg, of Schweidnitz, in Silesia, of an oval boiler, the design of which allows the use of heating-surfaces much greater than those usually employed in conjunction with moderately thick plates.

The boiler—which is illustrated in the original—is intended for a pressure of five atmospheres. The shell is oval, the major axis being placed horizontally; the extreme diameters are 8 feet 6·8 inches and 6 feet 6·7 inches; the length, 27 feet 10·7 inches; the ends are flat. The thickness of the shell is 0·51 inch, that of the end-plates 0·79 inch, with double-riveted lap-joints.

The two flues are of corrugated plate for a length of 13 feet 7·8 inches at the front end with a mean diameter of 3 feet 3·4 inches; the middle portion of each flue, 10 feet 7·9 inches long, is cylindrical and smooth, with a diameter of 3 feet 1·4 inch, and contains six Galloway tubes; the remaining length of 3 feet 6·8 inches tapers from 3 feet 1·4 inch to 2 feet 9·47 inches diameter. The products of combustion, after traversing the flues, return under the lower half of the shell, and pass off over the steam-space into the chimney. There are two domes, each of 27·56 inches diameter and 34·65 inches high. The total weight is about 18 tons 10 cwt. The boiler is used to work the sugar manufactory Neuhof.

Experiments were undertaken to test the evaporative capacity of this boiler on January 13th, 1887.

The following are the leading particulars and more important results :—

Total heating-surface in contact with water . . .	1,048·34 square feet.
„ grate-area	21·53 „
Free „ „	6·56 „
Ratio of total grate-area to heating-surface . . .	1 : 48·69
Surface for evaporation	207·64 square feet.
Water-space	640·64 cubic feet.
Steam-space	264·52 „
Area of damper	8·71 square feet.
Duration of trial	10 hours.
Coal used per hour	504·45 lbs.
„ „ and square foot of heating-surface . . .	0·48 „
„ „ „ of grate-area	23·45 „
Ash and waste	12·15 per cent.
Mean temperature of atmosphere	55·4° Fahr.
„ in smoke-stack	577·4°
Opening of damper	4·02 square feet.
Working pressure of steam per square inch . . .	55·12 lbs.
Temperature of feed-water	116·6° Fahr.
Water evaporated per hour	4431·24 lbs.
„ „ and square foot heating-surface } . . .	4·23 „
„ „ „ „ evaporation-surface } . . .	21·34 „
„ „ „ „ grate-area	205·81 „
„ per lb. of coal	8·785 „
„ „ „ from and at 212°	9·90 „
„ „ „ combustible	10·0 „
„ „ „ from and at 212°	11·28 „
Calorific value of coal as calculated from analysis .	11,997·0 B. T. U.
Efficiency	79·75 per cent.
Distribution of heat, per cent. :—	
Absorbed by steam	79·75 „
Loss by products of combustion	18·08 „
„ cinders	0·09 „
„ conduction and radiation	2·08 „
Ratio of air actually used to that required by theory	1·74 „

The feedwater was measured by a “Decker” water-meter, which was ascertained by careful tests to indicate 0·037 per cent. in excess of the quantity actually passed through.

G. R. B.

Spherical Check-Valve for Steam-Boilers. By — HIRSCH.

(Bulletin de la Société d'Encouragement, Paris, 1887, p. 265.)

The spherical check-valve is designed to avert the dangerous consequences of a sudden rupture in a steam-boiler or a steam-pipe, by instantly closing automatically the passage way for the escaping steam. A hollow ball-valve of gun-metal is enclosed within a roomy spherical box or case, forming part of the steam-pipe, which is horizontal. The ball, under normal conditions, lies at the bottom of the case, where it is partly out of the way of the passing

steam and opposes but little resistance to its passage. Two alternative seats facing each other are formed for the ball, one to the right and one to the left; and if, in consequence of a rupture, a violent current of steam is set up within the pipe and through the ball-case, the ball, induced by the current, rolls upwards towards either one seat or the other, and by closing the opening the flow is interrupted. The top of the ball-case is made with a cover which can be removed for purposes of inspection.

There are three means of adjusting the check-valve:—By the diameter of the ball, by its weight, and by the depth of the case in which it lies. The contrivance has been subjected to many experiments with good results.

D. K. C.

Device for Washing and Testing Boilers.

(American Machinist, May 28, 1887.)

This is a special injector, made by the Rue Manufacturing Company of Philadelphia, for washing out and proving boilers. The injector will work against a pressure from three to five times the pressure of the steam which drives it, and can therefore be very conveniently used for applying hydraulic tests with hot water, a pressure-gauge being attached to the instrument for that purpose. It is claimed that hot water is much more suitable for testing boilers than cold, and the injector dispenses entirely with the usual test-pump.

W. P.

Lubricating High-Speed Journals. By A. J. SHAW.

(American Machinist, Feb. 26, 1887.)

The writer, in No. VI of a series of Papers on "Suggestions in Machine Designs," describes a method with which he has attained excellent results, and which he believes to be new, applicable more especially to loose-running wheels or pulleys.

The pin on which the pulley runs is bored up the centre, and one or more small holes are drilled through the shaft to meet the centre hole; in the cross-holes loose pins are placed. The pins rest against the bore of the wheel, and are kept in vibration by the motion, and so keep up a flow of lubricant, after the manner of the stylographic pen or the needle lubricator. The oil is supplied through the centre hole.

W. P.

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Petit and Fayol's Frictometer. By A. TRESCA.

(Bulletin de la Société d'Encouragement, Paris, 1887, p. 549.)

The "frictometer" is an apparatus for measuring friction of shaft-journals, designed by Messrs. Émile Petit and Henri Fayol. A short shaft is carried horizontally in two fixed bearings, between which a fast and a loose pulley are mounted on the shaft. The shaft is prolonged by an experimental shaft on which the test-journal is formed. This journal is embraced by a bearing-sleeve, in one piece, fixed in a frame representing the cover of an ordinary bearing. This frame is loaded by means of a lever weighted at one end, and taking a knife-edge bearing on a parallel-motion connected to the frame, in such a manner that the frame is at liberty to swing or oscillate on the experimental journal, whilst the load continues constant. A swing-beam is fastened to the frame, for the purpose of measuring the tangential resistance between the journal and the bearing supported by it. The outer end of the beam is connected to a float within a cylinder containing water, and the float rises and falls proportionally as the frictional resistance diminishes or increases, the variation of resistance of the float depending on the less or greater head of water acting on it from below. Simple means of continuous registration are attached to the apparatus.

A frictometer has been installed, amongst other places, in the oil and grease manufactory of Mr. Allaire, at Levallois-Perret. Mr. Tresca testifies to its very satisfactory action. It can be employed for the study of the nature and mode of application of lubricants, the form and dimensions of journals and bearings, and the best conditions of speed or of load.

D. K. C.

Drilling Holes. By FRED J. MILLER.

(American Machinist, September 10, 1887.)

Precise accuracy in drilling and boring holes is no mean part of the machinist's business, and in certain kinds of work requires more care and skill than any other operation.

In many shops the drilling-machines are regularly abused, so that machines which are good to start with are soon rendered unfit for good work. If a machine which is intended for fine work comes into a shop, it should first be provided with a centre fitted to its spindle, and turned true in its place; if this is done, it is only necessary to mark the centre of any hole which is to be drilled or bored; set the centre mark directly under the point of the spindle centre, fasten the work and proceed.

Whether the work is heavy or not, if considerable accuracy is required, it may be secured by making small centre marks, setting

the work in position by the spindle centre, and using a short boring-bar for finishing the hole.

One or other of two conditions usually governs the location of holes in a piece of work. Either they must be placed at some given distance from other holes or working points, this distance being determined by direct linear measurement, or they must duplicate some piece of work already done.

Taking the case of holes, the distance between which is to be determined by measurement. For a large class of work the process of striking circles from the given centre, marking these circles with a centre-punch, and keeping the drill within the circle by "drawing" it with a small round chisel, may be employed; this method, however, is not sufficiently accurate for exact work, as it is extremely difficult to get a drill started exactly right within a scribed circle, even if the circle itself is true, which is unlikely when marked out with dividers.

The method indicated at the commencement of this article will give very good results; but when possible a brushing should be provided for the boring bar to work through.

When it is necessary to set out the work and mark the centres of the holes with the punch, the holes can be made true with the centre marks by means of the following device:—A piece of steel is provided into which two bushings are driven, having holes of any convenient size. These bushings are lapped out and ground true before being driven into the plate, and twist drills are ground to fit them as closely as practicable. Two plugs are ground to fit the bushes closely, having at the same time small conical points ground on them so as to be quite true. Then, supposing the holes to have been set out correctly, one of the plugs having been pushed through the bushing so that it projects a little below the plate, the point is put into the centre mark; then, holding it in position, the plate is pushed down on to the face of the work and clamped; next the plug is withdrawn, leaving the bushing exactly centred over the mark. Now the drill may be put in and the hole started, after which the plate should be removed to prevent wear of the bushing, and the drilling finished.

L. H. R.

The Milling-Machine—its Construction and Uses.

By JOHN J. GRANT.

(American Machinist, August 27, 1887.)

All machines that shape work in any manner may properly be called profiling-machines; therefore, the above machine being the subject of this Paper, it is necessary to define the machines generally termed profiling- or edging-machines.

A profiling-machine is a machine having one or more spindles

hung in a perpendicular slide adjustable both horizontally and perpendicularly, with a table for holding the work to be shaped; it is also provided with a former to shape the work by, and a guide for the same, which is termed a former pin.

The profiling-machine is seen to best advantage in the manufacture of guns, pistols, and all classes of work requiring irregular shaped pieces which are to be made interchangeable. It is also invaluable for doing a variety of straight work, such as cutting bevel slides where both sides of the bevel can be cut at one setting, working out "under-cuts," and many similar operations. The machine generally used has two spindles, employed respectively for roughing out and finishing. In doing work on the profiling-machine it is necessary as a rule to use a former; the former pin, being held close to the former by means of the handles working the table and spindle-head, is always the same distance from the cutter-spindle, so that the work produced must necessarily be of the same profile as the former.

Some machines are provided with an auxiliary spindle, which is used for cutting the formers directly from the model. This is a valuable adjunct, as the former produced in this way must necessarily be correct. It is necessary in machines not having this attachment to set out the former and work it to shape by hand.

The former spindle occupies the same position with regard to one of the spindles as the former pin does to the other, and is used to hold the former pin of the spindle nearest to it.

The spindles and slide are made to lift above the work, to allow the work and former to pass under the roughing or finishing cutter, as one or the other is not in use. Adjustable stops are attached to the slides and cross-slides of the spindles to regulate the height of the cutters, and to keep the spindle in position when cutting.

The former should stand about the same height as the work from the table; and both cutter and former-pin should be kept as short as possible to prevent springing or vibration.

Formers may be made of cast-iron; but for constant use steel is preferable; they are made about $\frac{3}{8}$ -inch thick, and with 15° taper, the former pin being of the same taper, so that by adjusting it perpendicularly the cutter is brought nearer to or further from the work. This allows for the reduction of the cutters by grinding.

For profiling the outside of work, an outside former is used; for inside work, or where a seat is required for another piece to fit into, an inside former is necessary. When milling plain edges, a shank-cutter of about $\frac{3}{4}$ -inch diameter is generally used; but to produce a shape other than a square edge, a cutter of a corresponding profile to the work is necessary.

L. H. R.

The Manfroni Freezing-Apparatus.

(Gesundheits-Ingenieur, 1887, p. 655.)

Most of the existing appliances for the rapid production of ice in small quantities, for domestic and medical purposes, involve the introduction of a rotating cylinder containing the liquid or other substance to be frozen into the freezing mixture. In consequence of the friction between this cylinder and the rough ice much unnecessary labour is expended in the use of the apparatus, and the withdrawal of the interior cylinder necessitates the removal of the freezing mixture and the repacking of the same each time the machine is used. The Manfroni apparatus obviates all these objections in a very simple way. The outer vessel, containing the freezing mixture, is furnished with a metal gauze screen to form the pocket into which the rotating cylinder drops. The gauze protects the cylinder from immediate contact with the rough ice, but enables the freezing mixture to act upon the substances contained in the inner cylinder. The cylinder can be withdrawn and replaced without disturbing the freezing mixture, and the production of ice takes place with great rapidity. Water can be frozen into perfectly transparent ice, free from air-bubbles, in three minutes; and wine, milk, beef-tea, &c., can readily be solidified.

G. R. R.

Centrifugal Ventilators on the Ser System.

By MAX DE NANSOUTY.

(Le Génie Civil, vol. xi., 1887, p. 373, 1 plate and 6 woodcuts.)

Though the working of centrifugal ventilators, so often employed for supplying air to forges and furnaces, and for ventilating mines and other places, is very simple, the theory is intricate, owing to the difficulty of ascertaining the real movements of the air in the various parts of the apparatus. Since Mr. Ser brought forward, in 1878, his theory based upon mechanical principles,¹ numerous ventilators have been constructed in accordance with this theory; and experiments with these machines have confirmed the soundness of his views, and the superiority of the ventilators. Illustrations are given showing the form and details of the two principal types of ventilators, suited for forges or furnaces, and for mines. The first consists of a wheel, 1 foot 8 inches in diameter, formed of a circular plate, on which are fixed thirty-two curved vanes, extending from the outer edge to within 6 inches of the centre, their width decreasing with their distance from the centre according to a

¹ Mémoires de la Société des Ingénieurs Civils, 1878, p. 414.

special curve. The outer air is sucked in from two openings round the shaft, and passing between the vanes, is discharged into a spiral chamber, which, by its increase in size, enables each current of air to flow out unimpeded, without the eddies and whirlwinds which usually cause a great loss of *vis viva*. The suction-ventilator for mines is similarly arranged: the circular plate has a diameter of 6 feet 7 inches, on which the thirty-two curved vanes are fixed, $1\frac{1}{4}$ foot radial height, and a width varying with the distance from the centre, the curvature of the vanes and their width being regulated by the diminution of pressure and discharge required. This ventilator differs from the other merely in having a suction-chamber in connection with the mine, and a long, enlarging, conical mouthpiece from the outlet of the spiral chamber for reducing the velocity of the air and converting it into pressure. The most sure and simple measure of the value of a ventilator, independently of its motor and its passive resistances, is its pressure efficiency. This attains 0.70, at its maximum, in the Guibal ventilator; it varies between 0.32 and 0.46 in the English ventilator of Schiele, and reaches only 0.30 in the German ventilators of Winter and Pelzer; whilst in the two Ser ventilators experimented on, having diameters of 6 feet 7 inches and 4 feet 7 inches, it attained 0.93 and 0.85 respectively. The discharging power of the Ser ventilators is equally large; and they extract generally eight to ten times the volume dealt with. The smaller machine, which is specially applicable to narrow mines, with a velocity of 400 revolutions a minute, and an equivalent orifice of $5\frac{1}{2}$ square feet, discharges $15\frac{1}{2}$ cubic yards per second; and for a mine of $10\frac{1}{2}$ square feet of sectional area, with the same velocity, its discharge is 26 cubic yards. The machine of 6 feet 7 inches diameter, running 280 revolutions per minute, with an equivalent orifice of $10\frac{1}{2}$ square feet, extracts $32\frac{1}{2}$ cubic yards per second, with a depression of $3\frac{1}{2}$ inches of water; whilst for a mine of $21\frac{1}{2}$ square feet, at the same velocity, it extracts $52\frac{1}{2}$ cubic yards, with a depression of $2\frac{1}{4}$ inches. The dynamometrical efficiency proved equal to 60 per cent. Tables and diagrams are given showing the results of some of the experiments; and a comparison of the two experimental ventilators indicates that for supplying a mine with about 20 cubic yards of air per second, having an orifice not exceeding $7\frac{1}{2}$ square feet, the smaller machine furnishes a depression of from $2\frac{1}{4}$ to $3\frac{1}{2}$ inches, as compared with only $2\frac{1}{4}$ to $2\frac{3}{4}$ inches with the larger machine. Within this limit, therefore, the small machine is the best; and it attains its maximum of depression with an orifice of about $5\frac{1}{2}$ square feet. For orifices ranging between $7\frac{1}{2}$ and 13 square feet, the larger machine affords the greatest depression, attaining a maximum exceeding $3\frac{1}{2}$ inches, with an orifice of $10\frac{1}{2}$ square feet. Beyond 13 square feet, the efficiency of the ventilator of 6 feet 7 inches diameter declines, and larger machines are requisite. Mr. Ser constructs ventilators ranging from $6\frac{1}{2}$ inches to 13 feet; and the results which he undertakes to obtain with different sizes are given in the following Table:—

Diameter.			Equivalent Orifice.	Depression of Water.	Volume of Air per Second.	Revolutions per Second.
Metres.	Ft.	Ins.	Square feet.	Inches.	Square yards.	
1·0	3	3½	3½	3½	10½	560
1·4	4	7	6	3½	19½	400
2·0	6	7	13	3½	42	260
2·5	8	2½	20	3½	65	210
3·0	9	10	28½	3½	94	160
4·0	13	1½	49½	3½	163	120

The investigation of the results of the experiments not merely demonstrates the progress which has been achieved by these ventilators, but also proves, by the close accordance of the results with Mr. Ser's theory, that ventilators have now been placed on a sound and precise theoretical basis.

L. V. H.

The Catrice Apparatus for Re-lighting Safety-Lamps.

(Société de l'Industrie Minérale, Comptes rendus mensuels, October 1887, p. 237.)

Unlike the Wolf system, which can only be applied to lamps burning a volatile mineral oil, such as benzine, Mr. Catrice's apparatus for re-lighting safety-lamps without opening them is applicable to ordinary oil-burning lamps. It is fixed in the lamp, and consists of an eight-chambered revolving barrel, resembling the breech-block of a revolver, $\frac{3}{4}$ inch diameter, and 1 inch long, each chamber being large enough to contain a small highly inflammable match, which is inserted before the lamp is closed. When brought into the proper position, each chamber in turn can be uncovered by means of a small slide, and a small punch pushed through the chamber forces the match through a spring clip with rasp faces, which ignites the match close to the wick.

The apparatus is by no means perfect, as it may happen that if the lamp is full of smoke, or choke damp, the match will be smothered before the wick catches. This is especially the case with the Mueseler type of lamp. On the other hand, in a fiery atmosphere, an empty chamber accidentally brought fair with the orifice presents an opening which, by its small diameter in proportion to its length, might shoot out a tongue of flame, as if from a miniature pistol barrel, and cause an explosion. Still, it is a step in the right direction.

The description is accompanied by an engraving of the apparatus.

W. S. H.

On the Molecular Changes in Iron at High Temperatures.

By — TEMNIKOFF.

(Gorny Jurnal, February 1887, p. 308.)

There appeared, last year, in the *Comptes Rendus* of the Paris Academy of Sciences, some articles on the extremely interesting question of the molecular changes which take place in the hardening of iron and steel. So long ago as 1873 Barrett¹ showed that an iron wire, heated white-hot, and suffered to cool down to a dull red heat, commenced to glow more brightly again, and that the magnetic properties of the iron were changed. He called this phenomenon "recalcescence." Pionchon and La Châtelier² proved, by various methods, that molecular changes took place in pure iron at temperatures approximating to 700° Centigrade (1,292° Fahrenheit).

The investigations of Pionchon showed that the specific heats of alloys of platinum with 10 per cent. of iridium, and with 14 per cent. of palladium, were the same as would result from a simple mixture of the metals in the proportions stated. The quantity of heat required to heat platinum, copper, and the above-named alloys from 0° to t increases in a regular manner with the increase of t , and may be expressed by the following formula—

$$q_0' = At + Bt^2$$

where A and B are coefficients, which must be determined by experiment.

In the case of iron, Pionchon found several anomalies. From 0° to 100° (32° Fahrenheit to 212° Fahrenheit) the specific heat of iron, according to Regnault, is 0.1137. The curve corresponding to the equation just given is of parabolic form, but between 680° and 730° (1,256° Fahrenheit and 1,346° Fahrenheit) the curve suddenly changes, and a very large absorption of heat takes place. Between 750° and 1,000° (1,382° Fahrenheit and 1,832° Fahrenheit) the curve becomes almost a straight line, and the specific heat is equal to 0.213, or nearly twice as great as it was at the lower temperatures.

Pionchon's experiments were made with a very pure iron known as "fer doux du Berry," which, on analysis, showed mere traces of carbon and silicon, and it could neither be hardened nor tempered. The quantity of heat, q_0 , required to raise 1 gram to a temperature t between 0° and 660° (32° Fahrenheit and 1,220° Fahrenheit) is found by the following parabolic expression—

$$q_0' = 0.11012t + 0.00002533t^2 + 0.00000005466t^3.$$

Between 660° and 723° (1,220° Fahrenheit and 1,333° Fahrenheit)

¹ "Philosophical Magazine," vol. xlv. p. 472.

² *Comptes Rendus de l'Académie des Sciences*, vol. cii. p. 670, 1454.

the value q_0' increased much more rapidly and satisfied the following expression—

$$q_0' = 0.57803t + 0.00143598t^2 + 0.000001195t^3.$$

From 723° to $1,000^\circ$ ($1,333^\circ$ Fahrenheit and $1,832^\circ$ Fahrenheit) the capacity for heat is expressed by the linear equation—

$$q_0' = 0.218t - 39.$$

The specific heat of iron in the last stage is $= 0.218$, so that if the atomic weight of iron is to be calculated by the well-known law of Dulong and Petit, and if the product of the atomic weight into the specific heat be taken about 6, the atomic weight of iron would become only 28 instead of 56, the value usually received.

In order to determine whether the changes of temperature produced changes in the very substance of the metal, or only in its apparent structure, Pionchon repeated his experiments with chemically pure iron, prepared by passing hydrogen gas over red-hot oxide of iron; that is, he produced pure iron from a substance having no special structure. The iron obtained was, in appearance, like spongy platinum, of a beautiful light-grey colour, and did not contain a trace of Fe_2O_3 , or of hydrogen. The experiments with this material agree very closely with those performed with ordinary soft and pure iron.

According to the observations of Becquerelle, iron, at temperatures near to 600° ($1,112^\circ$ Fahrenheit), undergoes a great change in its magnetic properties; its power of attracting a magnet is greatly reduced. This anomaly is also exhibited by nickel at 400° (752° Fahrenheit), and cobalt at a bright red heat. It is probable, therefore, that these metals will likewise prove irregular in their specific heats at high temperatures. The latest investigations on the molecular changes of iron, caused by heating, have been pursued by Osmond.¹ He has examined the question as to whether the phenomenon of "recalcescence" is only a consequence of the heat set free by molecular changes, or whether it is not influenced by the carbon contained in iron and in steel. With this view he instituted experiments on the heating and cooling of rods between ordinary atmospheric temperatures and 800° ($1,472^\circ$ Fahrenheit), and measured the temperature by means of a thermopile, composed of pure platinum and the native metal, actuating a d'Arsonval galvanometer.

In iron containing 0.16 per cent. of carbon the molecular change which takes place does not affect the rate of cooling much, the maximum effect appears, in heating, at about 723° ($1,333^\circ$ Fahrenheit), and in cooling at about 749° ($1,380^\circ$ Fahrenheit). The retardation in the rate of cooling, which is 1.8° Fahrenheit in one second, does not continue more than about three seconds. The experiments did not give very regular results, so that the changes in the

¹ Comptes Rendus, vol. ciii. p. 743.

molecular state of the iron could not have been complete under the conditions which obtained, that is to say, under rapid heating and cooling, in an atmosphere of nitrogen, between the temperatures of 20° and 800° (68° Fahrenheit to $1,472^{\circ}$ Fahrenheit).

If steel, containing 0.57 per cent. carbon, be cooled from 800° ($1,472^{\circ}$ Fahrenheit) at the rate of 1.8° Fahrenheit per second, then the first retardation in cooling is observed at between 736° and 690° ($1,356^{\circ}$ Fahrenheit and $1,274^{\circ}$ Fahrenheit). After that, the curve of cooling becomes regular, but at about 675° ($1,247^{\circ}$ Fahrenheit) the thermometer suddenly ceases to fall, rises to 681° ($1,258^{\circ}$ Fahrenheit), and after stopping at that temperature for some twenty-five seconds, commences to fall regularly again. Consequently, when steel contains certain proportions of carbon, two distinct phenomena become apparent, one consisting in the molecular changes in the iron indicated by Pionchon and Le Châtelier, and the other in an action corresponding to the recalescence of Barrett, depending upon a change in the relations between the iron and the carbon. If steel, cooled down to a mean temperature between the two critical temperatures above mentioned, be plunged into water, and afterwards treated with nitric acid, it will, in spite of proving soft under the file, show that its carbon has assumed the form which it bears in hardened steel. Hardened at a temperature above 736° ($1,356^{\circ}$ Fahrenheit), it behaves like ordinary hardened steel; while at temperatures lower than 675° ($1,247^{\circ}$ Fahrenheit), it cannot be hardened at all. These facts show that the hardening of steel depends upon molecular changes which cannot fully take place during rapid cooling in the presence of carbon. On heating the material, the two phenomena unite, and as the result there is a retardation in the rise of the thermometer between the temperatures of 719° and 747° ($1,326^{\circ}$ Fahrenheit and $1,377^{\circ}$ Fahrenheit).

In hard steel containing 1.25 per cent. of carbon, the two phenomena coincide, not only in heating, but in cooling. In heating there is a protracted retardation in the rise of the thermometer between 723° and 743° ($1,333^{\circ}$ Fahrenheit and $1,369^{\circ}$ Fahrenheit), the maximum between 730° and 736° ($1,346^{\circ}$ Fahrenheit and $1,357^{\circ}$ Fahrenheit); and in cooling, a sudden stoppage of the fall of the thermometer at 696° ($1,285^{\circ}$ Fahrenheit), and a rise at 704° ($1,299^{\circ}$ Fahrenheit), the retardation in the fall of the thermometer lasts almost a minute, at a rate of cooling equal to 2.4° Fahrenheit per second.

Therefore an increase in the proportion of carbon contained in steel is followed by a fall of the temperature at which molecular change takes place, while the temperature at which recalescence commences becomes higher, and the two phenomena coincide in hard steel. The following conclusions are arrived at:—

1. A rate of heating within the limits of from two to ten seconds for 1.8° Fahrenheit does not produce a perceptible influence on the position of the critical points.

2. The position of the critical points is lowered where cooling is rapid. In hardening, no anomalous effects are observable, but the

heat, corresponding to the molecular changes which have not taken place, remains in the steel.

3. The position of the critical points is somewhat lowered as the temperature at which the quenching of the steel commences is raised.

4. During the time that tempering goes on after hardening, the heat of hardening is given out gradually, and not at once.

The article concludes with some remarks on the thermo-electrical thermometer made use of to measure the higher temperatures.

W. A.

Researches into the Internal Stresses in Cast-iron and Steel.

By General N. KALAKOUTSKY, I.R.A., St. Petersburg, 1887.

This little book, of one hundred and twenty-six pages, contains the results of sixteen years of patient investigation into the internal stresses inherent in masses of cast iron and steel. The Author has served for many years on the Scientific Committees appointed by the Imperial Government to direct the construction of its ordnance, and has consequently enjoyed exceptional advantages in conducting the investigations which he has, at length, made public.

General Kalakoutsky commences by explaining the formulæ according to which the strength of guns is usually calculated, and he points out the effects, whether injurious or beneficial, which the existence of internal stresses may produce. He next describes the instrument which he constructed for the purpose of measuring, to the $\frac{1}{10,000}$ part of a millimetre, the diameters of rings parted out of disks or slabs cut off gun tubes, and hoops, and off projectiles, and explains his method of experiment which was to cut up the disks into a number of concentric rings, measuring the mean diameters of such rings when in the mass, and after being cut out. The changes in the lengths of the diameters give the means, by the aid of formulæ which he explains, of arriving at the stresses which must have existed in the several rings. The amount of labour bestowed on the measurements may be estimated from the fact that a disk cut from a 12-inch gun which was divided into twelve rings, and which was measured along six diameters, necessitated six hundred measurements, and occupied two months of continuous work.

The Author then proceeds to indicate the practical method of utilizing the observed measurements, illustrating them by numerous tables, which are the records of thirty experiments, selected out of the eighty-seven actually made, and by many diagrams in which the calculated values are exhibited graphically.

The practical results which have followed from these investigations appear to be of the highest importance, not only with respect

to the strength of guns and the efficiency of projectiles, but also in connection with crank and screw shafts, and other massive constructions in cast iron and cast and wrought steel. The work is now being translated into English, and as it will then be easily accessible, there is no occasion to give a more extended notice.

W. A.

The Savona Ironworks. By CYRIAQUE HELSON.

(Revue Universelle des Mines, 1887, vol. xxii., p. 182.)

As the site of the works established in 1861, by Messrs. Tardy and Benech, on the peninsula of the old port of Savona, was required for the extension of the harbour, the Italian Government granted them, in 1880, a new site of 39,100 square yards, on the condition that their new works should be in no way inferior to the former.

Savona, which is on the Mediterranean shore, twenty-five miles from Genoa, is one of the most important ports of arrival for English coal, as the Ligurian ironworks are all situated on the seashore between Genoa and Savona. These works, whose collective output has increased from 15,000 tons of iron in 1874, to 80,000 tons of iron and 20,000 tons of Siemens-Martin steel per annum at the present time, use scarcely anything else but old rails and scrap-iron of all descriptions, not only from Italy, but also from abroad, and especially from the Levant. The iron produced is as a rule only of medium quality, inferior to that from the Alpine valleys.

The arrangement of the new works at Savona, comprising forge, foundry, fitting-shop, and rolling-mills for all sorts of special sections of bars, joists, iron, and large flats and plates, which until then had been almost entirely imported, was entrusted to the Author. Being close to the harbour of Savona, which is supplied with hydraulic cranes, the coal and the scrap-iron are delivered at once into two adjacent yards. The latter, amounting to some 50,000 tons a year, which, allowing for from 15 to 20 per cent. of waste, corresponds to an output of 40,000 tons, consisting of old rails, some hundreds of 4- and 5-ton guns formerly used by Arabi Pasha (which have to be broken up by dynamite), shot and shell from Egypt, old sugar-mills, fragments of iron vessels, material from the St. Gothard tunnel, &c., is first smashed by a steam-monkey, and then sheared ready for piling. No light scrap is accepted, although turnings are sometimes used for special purposes.

This is the largest establishment of its kind in Italy, employing 1,200 hands, and fourteen engines with an aggregate of 1,200 HP., of which five are employed to drive the rolling mills, and the others for the fans, shears, saws, pumps, punches and machine-tools. The main building consists of three parallel sheds 361 feet long. The central one, containing the rolling-

trains, is 82 feet wide, and the others, one on each side, each 57 feet wide, contain the furnaces and the finishing machinery respectively. There are two steam-hammers, one of 2 tons for puddling, the other of 6 tons for shingling the piles; one puddling-train, two merchant-mills, one ditto for sheets, and one universal for large flats.

There are eight double puddling-furnaces arranged in pairs, with a vertical boiler to each pair. The pig comes partly from England, partly from Messrs. Tardy Brothers' blast-furnace at Vada, near Leghorn. The 2-ton steam-hammer, which is so arranged as to be within 52 feet of the farthest furnace, is of simple construction, single-acting, with an air-cushion above the piston, which is $21\frac{1}{2}$ inches diameter, with a stroke of 4 feet 7 inches. It is designed for working with steam of low pressure, and was built in Belgium. It cost £523, including foundation, fixing, and import dues.

The foundations of each engine, and of the roll-train which it drives, is practically a monolith, being composed of single blocks of a specially-prepared concrete; and the engines themselves, which are of the "steam-hammer," or inverted vertical type, working at 70 lbs. pressure, condensing, and fitted with expansion gear of the Meyer type, are placed in pairs, so that one man can frequently attend to two engines and their trains. The engine for the heavy train has a cylinder $31\frac{1}{2}$ inches diameter by $33\frac{1}{2}$ inches stroke, and makes 70 revolutions a minute. The fly-wheel is 23 feet diameter, and weighs 35 tons. The heavy train has four sets of three-high rolls, $19\frac{3}{4}$ inches diameter, which can be changed as often as necessary without dismantling the train. This train will roll joists from $3\frac{1}{2}$ by $1\frac{1}{2}$ inches, up to $8\frac{3}{4}$ by 4 inches, and channel bars 4, $5\frac{1}{2}$, and 10 inches wide.

The light train is driven by four ropes of Baden hemp, which experience has shown to be superior to either manilla or cotton. After some unsatisfactory experiments with gearing, double and triple belts, 12, 16, and even 27 inches wide, were tried, and answered very fairly, provided the joints were carefully made, straight, and cemented, so as to be no thicker than the belt itself; but ropes 2 inches in diameter, with splices from 8 feet to 10 feet long, were found the best of all. As compared with gearing and belting, the former required a stoppage of fourteen days every two years, in order to re-cog the mortice-wheel, while a belt takes about six hours to replace. If a rope breaks, it can be replaced in two hours, while work can be continued with three, two, or even one rope, until a convenient opportunity for stoppage occurs. The engine, of the same type as the others, has a cylinder $21\frac{1}{2}$ inches diameter, and $31\frac{1}{2}$ inches stroke. It makes 75 revolutions per minute, and cuts off at one-tenth of the stroke, with an injection-condenser. Although fresh water is used for the boilers, sea-water is used for condensation, the pump-plunger, valves, injection-cock, &c., being either cased with or made of brass.

The sheet train is driven direct by a vertical engine, of the

same pattern as those already described, with a cylinder 3 feet $3\frac{3}{4}$ inches diameter, and the same stroke, and is served by two steam elevators, one for the two-high rolls, $24\frac{1}{4}$ inches diameter and 5 feet 11 inches wide, employed on heavy plates, and the other for the three-high rolls of the same size, employed on medium plates. The universal train is driven by a similar engine, and served by a similar elevator. The pinions for both trains are of cast-steel, with helicoidal teeth, and work without noise. The housings, pinions, screws, gearing, &c., of both trains are all of the same pattern, so as to necessitate the least possible number of duplicate parts, and the advantage of driving these two trains separately is very perceptible, although rather more expensive. All the five trains are commanded by a single steam-travelling crane. In the universal train the vertical rolls are behind, instead of in front of, the main rolls, and the rolls are driven from the bottom pinion.

It is chiefly for heavy piles, and for those formed of shearings of plates, that shingling is performed under the hammer. They are thus more thoroughly welded, and the products are better, and with fewer wasters, than when the rolls only, which give a drawing as well as a compressive action, are employed.

The Paper is illustrated by a plate giving plan and section of the works.

W. S. H.

Hushavel's method of producing Wrought-iron and Steel direct from the Ore.

(Proceedings of the Imperial Russian Technical Society, 1887, p. 47.)

After stating that several communications respecting his process had already been made by various authors to the Technical Society and the Russian Mining Journal, Mr. Hushavel proceeds to give a brief history of his invention, and the most recent results obtained from it.

The main features of his furnace consist of a movable hearth fitted to a blast-furnace constructed partly of cast-iron, and partly of wrought-iron plates, the latter forming a double skin to the body of the furnace, the space between the skins being used to heat the blast. The Author illustrates his description by means of six plates, which show how his furnace has been gradually developed from the simplest form of cold-blast furnace, and explains how the development grew out of the various difficulties he had to encounter. His latest furnace was erected in 1886 at Count Strogonoff's Dobriansk Works. The construction is illustrated by means of two plates. The furnace is 26 feet high from the top of the movable hearth; 4 feet diameter at the top, and 5 feet at the widest part. The upper, or fixed portion, rests on four columns, and consists of a double boiler plate structure tapering slightly towards the top. The distance

between the two skins is 7 inches; they are connected at top and bottom by horizontal rings, and a spiral partition, making about nine turns, forms an air-passage winding round the inner case. The lower part of the furnace is of the usual form of an inverted truncated cone, and is formed partly of boiler plate and partly of a cast-iron ring, bolted up to the lower horizontal plate which unites the double skins. The thickness of the boiler-plate varies from $\frac{1}{2}$ inch to $\frac{3}{16}$ inch. The lower end of the cast-iron cone is formed into a square with rounded corners about 2 feet 6 inches across, and the whole is surrounded by a sheet-iron case, forming an air-space, which is in communication, by means of two pipes, with the space between the two skins of the upper part of the furnace. From the top of the cast-iron ring upwards to a height of 5 feet, the furnace is lined with firebrick from $1\frac{1}{2}$ to 2 inches thick, the cast-iron cone and the body of the furnace above the firebrick is not protected in any way.

The movable hearth is composed of six parts. A bottom casting fitted with four wheels and their axles, a movable false bottom attached to a stalk projecting through the bottom of the hearth, and provided for the purpose of starting the ingot when the hearth is being emptied; two sides each having four tuyere openings in two rows; and two sides with four slag-holes arranged in a vertical row. These pieces are connected together by means of bolts and nuts. The upper set of tuyere openings are surrounded by a water-space cast in the plates, and intended to keep the opening cool, and, finally, a pair of trunnions is provided for the purpose of tipping the hearth over and discharging the ingot. The hearth runs on to a platform, placed immediately under the furnace, and is raised or lowered by means of a balanced lever. Three hearths are required for each furnace. The tuyeres are arranged so that they can be readily inserted into any set of apertures provided for them. A complete furnace is composed of about 15 tons of cast iron and 7 tons of boiler-plate. The furnace was started at the end of June, 1886, but did not begin to work regularly till August in the same year. By the middle of November, 127 tons of ingots had been produced direct from magnetic ore, the ingots, in most cases, having been taken straight from the hearth to the hammer. The fuel used is wood-charcoal. The Author describes, in detail, the method of charging the furnace and of changing the hearths; he also dwells at some length on the difficulties he had met with, and the way in which they had been overcome. From magnetic ore containing 58 per cent. of iron, he obtains 52.4 per cent. of forge steel, and the loss in producing wrought iron is stated to be no greater than it is in a puddling furnace.¹ The paper is supplemented by eight tables, which give in great detail the results obtained in working the new furnace, and also a bill of quantities, giving the weight of each part.

W. A.

¹ Minutes of Proceedings Inst. C.E. vol. lxxvii. p. 546.

Charcoal-drying for Blast-furnaces in Sweden. By G. UHR.

(Jernkontorets Annaler, vol. xl. p. 229. P. Tunner Oesterreichische Zeitschrift für Berg-und-Hüttenwesen, vol. xxxv. p. 459.)

In Sweden two methods of drying charcoal have been adopted. The first of these, due to Mr. M. Lindberg, has been in use at Dalkarlshyttan for several years past, while the second, which was invented by Mr. G. Uhr, was first introduced at Bångbro and subsequently at Mokärnsbyttan, Horndal and Sandviker. The use of heated air as a drying agent is common to both methods, but the manner of applying it differs considerably. At Dalkarlsbyttan the charcoal to be dried is loaded into wire baskets, placed upon wagon-frames running on rails, in a long walled tunnel which is continually supplied with a current of warm air. Owing, however, to the free space necessarily left between the baskets and the side wall, the air could only be brought very imperfectly into contact with the contents of the baskets, and therefore the drying went on very slowly, and fans were required at either end of the chamber, one blowing and the other exhausting, which rendered the apparatus large and expensive.

In the newer arrangement the charcoal is contained in covered sheet-iron tubs with perforated bottoms, which can be closed by conical covers connected by means of a pipe with a ventilating fan, so that the air may be forced through the contents.

At Bångbro and Mokärnsbyttan the heated air passes from above downwards, while in that at Horndal the direction of the current is from bottom to top, which not only simplifies the apparatus, but also facilitates the working.

In some cases the air for drying was heated by passing it over the pig-iron beds or by placing blocks of slag from the moulds upon a turn-table, which was slowly revolved through a domed chamber having an outlet in the roof connected with the fan; but the results so obtained were unsatisfactory, as the air could not be heated above 30° or 40° Centigrade, and when the iron was used for the direct Bessemer process, or run into first fusion castings, part of the heat was no longer available. In the newer form of the apparatus, therefore, the throat-flame, or the hot burnt gases given off from the top of the furnace, is utilized by placing a pipe with a wind bore of iron wire a few feet above the top of the furnace, and connecting it with a fan which draws the hot gases, and after diluting them with air when necessary forces the mixture through the charcoal contained in the tubs. The temperature of the current is so regulated that it never reaches 100° Centigrade, in order that all chance of ignition of the coal may be avoided. About 80° is considered to be the most desirable temperature, but even at 40° or 50° the drying goes on tolerably quickly as the volume of air used is considerable, and its final temperature is only from 15° to 30°.

When the local conditions allow, the gases are drawn by a fan,

5 feet in diameter, making 400 to 500 revolutions per minute through a 10-inch pipe, and discharged into a series of horizontal branch pipes, each having four apertures over which a corresponding number of open tubs are placed, at the level of the furnace-top. When, however, this cannot be done, the distributing pipes are carried to the floor of the charcoal-shed, and the tubs are brought up and removed by a railway, the transfer being effected by a crane which also serves as a weighing machine.

The capacity of the tubs is about 30 cubic feet, and the weight of the charcoal contained, which is mostly made from fir and pine with some from birch, varies from 82 lbs. when small and wet, to 60 lbs. for that in average condition, the loss by drying being 31·4 per cent. in the first instance and 8·42 per cent. in the second. The most carefully selected air-dried coals burnt in the forests (as distinguished from that carbonized from saw-mill waste) lost only from 3 to 4 per cent., but such material is not got in any very large quantity. The average length of time required for drying is about 3·47 hours. At Bångbro, where the process has been in use for five years, the furnace is found to work more regularly with dried coals, and to produce metal suitable for Bessemerizing, which was not previously the case. There has also been a saving of about 3·3 hectolitres (9 bushels) of charcoal per ton of pig-metal made. The cost of a drying apparatus suitable for a furnace producing 17½ tons of pig iron daily is said not to exceed £230, and Tunner considers that with suitable modifications it might be adapted to one making 35 tons. Where closed-topped furnaces are used the hot gases for drying may be obtained from the spent gases of the blast heating-stoves, as the loss of draught in the chimneys is supplied by the action of the fan.

H. B.

Silver-Ingot Melting at the U.S. Mint, New Orleans.

By F. F. CLAUSSEN.

(Transactions of the American Institute of Mining Engineers, July 1887.)

The method of casting silver ingots in use at New Orleans differs radically from that employed at any other mint either in the United States or elsewhere, and although the principal distinguishing feature, namely, the rotatory ingot mould, has been long used, it is comparatively unknown, so that a description is of interest.

The melting furnaces, four in number, are circular in plan, 2½ feet in diameter and 2½ feet high, in the clear, with cast-iron base and top plates, and boiler-plate casings for the sides. The cast-iron covers are dome-shaped, and are handled by a small crane and lever, each pair of furnaces having its own crane and ingot machine. The crucibles, made of fire-clay and black-lead mixture, are of No. 200 size, capable of safely melting from 8,600

to nearly 10,000 ozs. of standard silver, as against 1,800 ozs. at the Carson mint, and 2,600 to 3,000 ozs. at Philadelphia and San Francisco. Each crucible lasts out ten meltings. The average capacity of the four furnaces is about 70,000 ozs. per day of eight hours, and the yield may be increased to 100,000 ozs. when required. The crucible stands upon the bottom of an old one, cut down to 3 inches, and placed in the centre of the furnace. The best Connellsville coke is used, and although it is of much higher first cost than that from Alabama, it is cheaper in working. A small triangular black-lead crucible, holding about 40 ozs., is used as a pouring cup. The tongs and other tools are of the ordinary kind, with the exception of the stirrer, which is a $\frac{3}{4}$ -inch round iron rod, 5 feet long, with three 6-inch prongs at the bottom, to which are riveted a dished-plate 6 inches in diameter, perforated with $\frac{1}{2}$ -inch holes.

The rotatory mould or ingot-machine, which stands on a platform raised $2\frac{1}{2}$ feet above the floor, is a hollow cast-iron drum, $12\frac{3}{4}$ inches high, with twelve shallow rectangular grooves in the circumference, $1\frac{1}{8}$ inch wide, $\frac{1}{2}$ an inch deep (radially), and separated from each other by ribs $\frac{7}{8}$ inch wide. It is mounted upon a cast-iron standard, and, by means of a foot-lever and bevel gearing, can be rotated about its axis, so as to bring each groove in succession in front of a rectangular block of cast-iron, which has a sliding motion of $\frac{1}{4}$ of an inch to and from the drum. When pressed close to the latter the block and groove form the mould for an ingot of 53.6 ozs. weight. Both mould and block are cooled by a constant flow of cold water, supplied by a $\frac{1}{2}$ -inch pipe, in order to prevent by rapid cooling the segregation in the silver-copper alloy, after casting. The machine is operated as follows:—The workman presses down the treadle which first draws back the block from the position occupied during the last cast; then rotates the mould through one-twelfth of a revolution, bringing the next groove into position, when it is locked fast, and the block is pressed home by springs. The joint obtained is so close that no silver escapes through it, and only a slight feather edge is observed in the ingot after the moulds have been in use for some months. The silver is now poured into the open top of the mould, where, owing to the water cooling, it sets immediately, and at the next movement is exposed in the groove, being at a dull red heat. After three or four more have been poured, the first is removed and placed in a cast-iron box.

The machine was invented by Dr. J. L. Riddell, melter and refiner to the mint, between 1839 and 1849, and the first one, built by Mr. Tyler, who was at one time in charge of the coining operations, was introduced in 1847, since which date hand-moulds have never been used.

The advantages derived from the use of the rotatory moulds are principally a saving in the number of furnaces and in the labour employed, larger meltings averaging 8,600 ozs. being now made at one operation instead of 2,600 to almost 3,000 ozs. by the hand-mould method.

The objection made to working large charges, namely, that the melted alloy will differ between the first and last ingots, either by segregation or the burning out of part of the copper, owing to the long exposure in the furnace, is avoided by thoroughly mixing the metal before pouring, and by keeping the surface of the metal in the crucible covered with a thick layer of finely ground charcoal, which is constantly renewed as it burns away. The whole batch of bars is cast by means of the rotating mould in twenty minutes. After the melting down of the fine silver and addition of the necessary amount of alloy copper, the details of which operation are given at length in the Paper, the furnace is closed, and the fire urged to get the alloy as fluid as possible. When this is done the crucible is uncovered, and the stirrer, previously heated, is introduced, and churned up and down in the molten metal some four hundred times, in order to thoroughly mix the contents. When the stirring is completed the melter grasps the heated pouring crucible in his long-handled tongs, and takes out the first dip of about 6 ozs., which is granulated for assay by pouring it into a copper basin containing ice water; the second dip is cast as the first bar, and so on. Three intermediate dips and the last one are reserved for assay, and these are assayed separately, and when the difference in fineness between the first and last exceeds three-tenths of one thousandth (0.03 per cent.), the whole batch is condemned and remelted. This, however, very rarely happens. Although the lawful variation from the standard of 900 is ± 3 , the practice of the New Orleans mint is to condemn all ingots below 898½ or above 900½, in order to keep the coin as close to the legal standard as possible.

The ingots when removed from the mould are laid on the floor to cool, after which they are topped and the edges are filed, so as to leave a smooth, clean mass, with a solid top, and, when passed by the assayer, are delivered for coinage.

H. B.

The Desilverizing of Lead at Freiberg. By C. A. PLATTNER.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1887, p. 421.)

At Freiberg the substitution of Parkes's method of desilverizing by zinc for the Pattinson process, which has become general elsewhere, has not been found advantageous in consequence of certain special peculiarities in the lead there smelted. In the first place it contains too high a proportion of copper, nickel, cobalt, tin, antimony, arsenic, and bismuth to be fit for the zinc process without preliminary liquation and softening, whereby one principal advantage of the newer method is lost; and secondly, the silver contents being mostly large (60 to 120 ozs. per ton), the concentration for the refinery is nearly as rapidly effected by one method as by the other. The fact that production of flake litharge, for which there is a considerable commercial demand, is notably diminished when

zinc is used, constitutes a third objection; while, lastly, but more important than all, is the circumstance that the recovery of bismuth from the lead, which is one of the profitable operations of the works, can only be effected by the older process. While, therefore, it has not been found possible to take to zincking alone, a combination of the two methods has been developed which presents notable advantages over crystallizing alone. By this method lead containing 33 ozs. of silver, and upwards, is after previous liquation and softening when necessary, crystallized by the method of thirds into rich and poor portions, the former with 650 ozs. going to the refinery, while the latter, containing at most 33 ozs. and practically freed from bismuth, is finally desilverized by zinc. This is generally effected by three additions, each of which occupies about five hours, and as a similar time is required for melting down and cleaning the surface of the lead, the total period of working one charge is about twenty hours. The charge, consisting of 20 tons, of lead, requires about 4 cwt., or 1 per cent. of its weight of zinc for complete desilverization; 220 lbs. being used in the first addition, 165 lbs. in the second, and 88 lbs. in the third. About one-half of this quantity is subsequently recovered in the distillation of the rich lead zinc and silver alloy. The progress of the desilverizing is as follows:—

	Silver. oz. dwt.	Gold. oz. dwt.
Original lead	32 13	1 6
After first zincking . . .	8 3	traces
„ second „	0 13	none
„ third „	0 4·6	„

The zinc removed after the first addition is sufficiently rich for the liquation pot; but that of the second and third additions is put aside to be used in subsequent operations with fresh quantities of lead. By liquation the former product is divided into rich scum for distillation and argentiferous zincky lead, which, together with the poorer zinc skimmings, is returned to the desilverizing process.

The relative proportions of the different products obtained in the treatment of lead by the zinc process are:—

	Per cent.	Per cent.	Per cent.
1. Dross	0·35	containing	0·0004 gold 0·1 silver.
2. Rich scum	2·25	„	0·0153 „ 5·05 „
3. Lead	98	„	0·75 zinc 0·0007 „

The removal of the zinc from the desilverized lead is effected in the softening furnace at a red heat, the oxidation being effected either by a blast of air, or by the chimney draught alone. The crust first formed on the surface consisting of zinc and lead oxides, must be drawn with a rabble, but the proportion of the latter gradually increases until pure litharge is produced. The refining operation lasts nine hours; the proportion of zinc in the lead diminishes from 0·75 per cent. at starting to 0·16 per cent. in three hours, 0·01 in five hours, 0·0008 in seven hours, and 0·0002 in nine hours. The

latter quantity corresponds to 1·3 dwts. per ton. When the refining is finished, the softened lead is tapped into a cast-iron pot, from which, after skimming the final dross, it is cast into moulds for sale.

The rich scum in which the precious metals are concentrated contains in addition to 4·05 per cent. of silver, and 0·0153 per cent. of gold, 53 per cent. of lead, 40 per cent. of zinc and somewhat more than 2½ per cent. of copper. The zinc is removed by distillation on Morgan's patent process in a plumbago crucible with a domed head and lateral discharge-pipe. The condenser is a cast-iron box about 20 inches high, of rectangular horizontal section diminishing upwards, the capacity being about $\frac{7}{8}$ of a cubic foot. About 4½ cwt. of the alloy with 1 per cent. of charcoal powder is charged upon a layer of lumps of charcoal placed at the bottom of the crucible. When the latter is filled, the dome is luted with clay, and the space inside is packed with a further quantity of alloy introduced through the hole upon which the discharge-pipe is finally adjusted. The crucible is placed on a square wind furnace heated with coke, which requires to be twice filled with fresh fuel during the period of distillation, lasting from eight to nine hours. When completed, the zinc is collected in a lump of the shape of the condenser, while the lead remains in the crucible, covered by the unconsumed charcoal and any unreduced dross. This, when cleaned by skimming with a colander, is ladled out and passed to the refinery. The products of the distillation are:—

	Per cent.		Gold. per cent.	Silver. per cent.	Copper. per cent.
Rich lead . . .	57·17	containing	0·0186	7·35	
Crucible dross . .	5·85	„	0·0112	4·608	3·5
Zinc metal . . .	29·54				
Dust and scrapings	6·35				

The cost of working lead with 300 ozs. of silver per ton by the combined process is about 13s. per ton, or about 18 per cent. less than by the simple Pattinson process. With poorer lead (150 ozs. to the ton) the saving is larger, and amounts to about 21½ per cent.; and the precious metals are rather more completely recovered by the new method than by the older one.

H. B.

The Chlorination of Gold-Bearing Sulphides. By E. G. SPILSBURY.

(Transactions of the American Institute of Mining Engineers, July, 1887.)

The Author records some experiments on a method of working calcined auriferous pyrites in barrels, which has been developed by Mr. A. Thies from the earlier process of Mears. The ore to be chlorinated is treated in an iron barrel lined with lead, and provided with a manhole for charging and discharging on one side. The barrel is first partially filled with water, then a sufficient quantity of bleaching-powder is dropped in, on the top of which

1 ton weight of the roasted ore is charged. The amount of sulphuric acid required to decompose the bleaching-powder is then added, the manhole cover is fitted and secured, and the barrel is set in rotation. The above order of charging is necessary to prevent the acid coming in contact with the bleaching-powder before the barrel is closed. An arrangement known as a clay pop-valve has been devised, which enables the operator, without opening the barrel, to test the contents for an excess of chlorine gas. The proportion of chemicals used is 20 lbs. of bleaching-powder and 25 lbs. of acid per ton of ore. About six hours are required for the complete conversion of the gold into chloride, although the Author thinks that this may ultimately be reduced by nearly one-half.

When the conversion is completed the barrel is nearly filled with water, and revolved in order to dissolve out the gold chloride. The barrel is then opened and the liquor is decanted into large shallow filter beds; a second wash water is then given, and ultimately the whole charge is turned down in the ordinary way, and a final washing is given on the filter. The results obtained with this method have so far been very successful. Examples are given of the working of eight charges of an ore assaying 36.70 dollars per ton (about 1 oz. 17½ dwts.) in gold, in which the amount remaining in the tailings varied from a mere trace to about 1½ dwts., the average in the whole eight being 68 cents in value, or about 17 grains per ton. The ore was reduced in an extremely fine powder, about 99 per cent. passing through a screen of one hundred holes to the square inch, and 60 per cent. through one of one hundred and fifty holes. When a heavier charge was used and discharged directly from the barrel, nearly double the amount of wash water, as well as a much longer time, was required, and the tailings retained 5.68 dollars (5½ dwts.) per ton. No difficulty was encountered in filtering so long as the bed of ore did not exceed 3 to 4½ inches, but with a greater thickness it became almost impossible. Hence the advantage of the preliminary decantation of the enriched liquor in working such finely divided materials. The precipitation of the gold is done with ferrous sulphate in the ordinary way. Some inconvenience was at first encountered from the precipitation of lime and magnesia salts contained in the liquor, which began to show as a white cloud whenever the solution became neutral. This, however, was immediately removed by the addition of a small quantity of free acid.

The cost of working the process in North Carolina for roasting chemicals and powder is given at 3.15 to 4 dollars per ton. The amount of gold recovered being in all cases within a few cents worth per ton of that indicated by the difference between the original assay and that of the tailings. The gold produced is generally above 978 fine, while that obtained from the same ore by stamping and amalgamation rarely exceeds 897 fine.

H. B.

The Calcination of Calamine in Sardinia. By L. MAZZETTI.

(Rivista del Servizio Minerario nel 1885.)

In the island of Sardinia the mines of Malfidano and Planu Sartu produced in 1885, in addition to other ores, about 33,000 tons of calcined calamine, valued at £107,520, while a further quantity of 45,000 tons was obtained from other mines. These ores are mostly subjected to calcination before being exported, the operation being generally performed either in kilns or flat-bedded reverberatory calciners. In addition to these, two new forms of furnace have been latterly adopted at the dressing-floors of Buggerru and Monteponi.

At the former locality three Oxland calciners have been substituted for reverberatory furnaces. They are sheet-iron cylinders, lined with fire-brick, about 42 feet long, 2 feet 10 inches inside diameter, supported on four pairs of friction rollers, and inclined downwards at 1 in 18 from the flue towards the fireplace, which has a horizontal grate, $3\frac{1}{2}$ feet long and $3\frac{1}{2}$ feet broad. The cylinder is turned slowly about its axis by a screw and worm wheel, driven by steam-power, and makes about 15 revolutions per hour. The calamine, after undergoing a preliminary drying on the cast-iron plates covering the top of the furnaces, is charged into a hopper at the top or flue end, whence it passes by a self-acting feeding-tube into the cylinder, where it is continuously turned over in the current of heated gases by the rotating action of the cylinder, assisted by four longitudinal ribs projecting from the lining. About four hours are required to pass the ore through the cylinder, when it is discharged into a vault at the lower end, immediately in front of the fireplace. The loss of weight by calcination is about 28 per cent. The yield of calcined ore is about 12 tons from each furnace in twenty-four hours. The three furnaces, which have cost £975, are rather more effective than the five reverberatory calciners previously erected at a cost of £1,000, giving 36 tons, instead of 32 to 33 tons of calcined product daily. The comparative cost of calcination by the two methods is given as follows, computed per ton of furnished product:—

	Reverberatory Furnace.	Oxland Furnace.
	s. d.	s. d.
Wages	1 9·7	0 8·1
Fuel	3 11·1	3 2·7
Tools and sundries	0 4	0 2·7
Repairs and general charges	0 8·6	0 8·1
	6 9·4	4 9·6

The fuel used was a mixture of coal and lignite, containing 11·05 per cent. of ash, having a calorific power of 6,275. The coal cost about 28s. per ton. The fuel burnt in the furnace is

about 15·11 per cent. less in the Oxland than in the reverberatory, but this saving is reduced to 12·41 per cent. when that required for the engine is taken into account.

The Ferraris furnace adopted at Monteponi is a gravitating calciner, similar in principle to that of Moser used for calcining small spathic ore at Eisenerz, in Styria. It has a bed of 38·3 feet long, and about 6½ feet broad, inclined upwards from the fireplace to the flue at a slope of about 1 in 3½. The furnace is heated by a gas-producer burning lignite on a step-grate, and having an air-heating flue round the fireplace. Two similar beds are united in one block, and have a gas-producer and stack in common, the heat being regulated by dampers the flues, which direct the flame from one bed to the other as required. The ore, fed into the furnace through a hopper into a short vertical shaft at the upper end of the bed, forms a conical talus which is gradually driven down the slope as fresh material is added above, and falls over the slope at the bottom into a receiving-chamber, whence it is drawn at intervals of about four hours. The ore remains in the furnace from twenty-five to thirty hours; the yield, determined by a three months' working-trial, was from 20 to 21 tons in twenty-four hours, with a loss in calcination of about 25 per cent.

The fuel used was a lignite containing 12·5 per cent. of ash, with a calorific power of 5,050; the consumption being at the rate of 17·67 per cent. of the weight of the products. This lignite costs about 15s. 10d. per ton; the total calcining cost being:—

	s.	d.
Wages	1	9·5
Fuel	2	9·6
Repairs	0	2·2
	4	9·3

or a slight economy on the Oxland furnaces. This might probably be increased by a better consumption of the fuel in the gas-producer, the cinders of which contain about 35 per cent. of combustible matter.

H. B.

Aluminium and its Alloys produced by the Electric Furnace.

By R. VAN LANGENHOVE, Engineer, of Brussels.

(Annuaire de l'Association des Ingénieurs sortis de l'École de Liège, 1887, p. 27.)

After giving a brief account of the early history of the production of aluminium, previous to the invention of the Cowles and Mabery electrical furnace,¹ the Author proceeds to describe some of its applications and qualities, both pure and alloyed with various other metals.

Pure cast aluminium has a density of 2·56; forged, of 2·67, or

¹ Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 510.

only one-third that of forged steel. Melting point, about 700° Centigrade (1,300° Fahrenheit). It is the best conductor of heat and electricity yet known, and practically inoxidisable, even at high temperatures, except by hydrochloric acid.

Ordinary alloys, such as bronze, brass, German silver, &c., when combined with aluminium, are wonderfully improved, especially as regards tensile strength and resistance to corrosion.

Aluminium Bronze, containing 10 per cent. of aluminium, has a rich gold colour, a mean specific gravity of 7·23, or 20 per cent. less than gun-metal, and an average tensile strength of 7,000 kilograms per square centimetre, or say 100,000 lbs. per square inch. (Steel for guns, as specified by the English and German Governments, costing from 6 to 11 francs per kilogram, or 2s. 2d. to 4s. per lb., must have a strength of 4,900 kilograms per square centimetre, or 70,000 lbs. per square inch, with 15 per cent. elongation.) It can be cast, forged, or rolled, machined, planished, or polished, and may be repeatedly re-melted without deterioration or alteration of proportions, and only an inappreciable waste.

Aluminium Silver, composed of aluminium, copper, and nickel, makes excellent cutlery, will take an edge like steel, cuts the hardest wood, and does not require to be electro-plated.

Aluminium Brass.—The addition of aluminium, up to 10 per cent., improves ordinary brass, either as to its ductility, its colour, its tensile strength, or its resistance to corrosion, according to the proportion employed. An alloy with 13 per cent. is excessively hard and red-short, with a reddish colour. A further addition increases its brittleness, and imparts a blackish grey colour. With 25 per cent. its resistance is again increased. A mixture of 5·8 aluminium, 26·8 zinc, and 67·4 copper, has a tensile strength of 6,720 kilograms per square centimetre, or 95,500 lbs. per square inch.

Silicon Bronze (copper, tin, and silicon), another product of the Cowles electric furnace, when cast, has a tensile strength of 3,150 kilograms per square centimetre, or 45,000 lbs. per square inch. Drawn into wire, its tensile strength exceeds that of steel, with an electric conductivity two or three times greater. In addition, its lightness and its resistance to corrosion render it the best material known for telegraph or telephone wires. Thus, an iron telegraph wire, weighing 103 kilograms per kilometre, or 364 lbs. per mile, may be replaced by one of siliceous bronze of twice the strength, but weighing 26 kilograms per kilometre, or 92 lbs. per mile. In Prague, Trieste, Lemberg, Pilsen, and other places, it is exclusively employed for telephonic purposes. Examples are quoted where spans of 750, and even 800 metres (2,460 and 2,624 feet) from post to post, have been successfully employed, while the reduced gauge of the wires offers a decreased surface to the action of either wind or snow.

Aluminium Steel.—This is one of the most remarkable products of the Cowles electric furnace. Even a small amount of aluminium added to steel or iron produces extraordinary effects, tripling their

tensile strength, and increasing their resistance to corrosive action; 2 per cent., added to cast iron, gives it, besides other good qualities, a greatly increased strength; $\frac{1}{10}$ per cent., added to Siemens-Martin steel considerably reduces its melting-point, and consequently increases its fluidity, and its freedom from porosity and blow-holes.

The present *net cost* of production of aluminium in the metallic state by the Cowles process is about 4.50 francs per kilogram, or say, 1s. 8d. per lb.; ordinary aluminium bronze, 2.75 francs per kilogram, or 1s. per lb.; special aluminium bronze, 4.50 francs per kilogram, or 1s. 8d. per lb.; or, comparing equal volumes aluminium costs—

5 times more than zinc.	
21	„ „ cast-iron.
10	„ „ rolled-iron.
14	„ „ Bessemer steel.
4.4	„ „ Siemens-Martin steel.
15 per cent.	more than copper.
148.5 times less than pure silver.	
5½	„ „ forged steel for guns.

Again, in equal volumes, ordinary aluminium bronze costs about:—

2½ times more than brass.
64 times less than silver of 750 degrees fineness.
3.3 times less than forged steel for guns.

Special bronze, containing 10 per cent. of aluminium, costs for equal volumes about:—

4 times more than brass.
2½ more than gun metal.
42 times less than silver of 750 degrees fineness.

Owing to its bulk being three times as great for equal weights, at 3.30 francs per kilogram, or 1s. 2d. per lb., aluminium would be cheaper than the same weight of copper at 1.20 franc per kilogram, or 5d. per lb.

To compete with steel at 30 francs per 100 kilograms, or 12s. per cwt., its price for the same weight must be reduced to 115 francs, say 5d. per lb., or 46s. 8d. per cwt.

At 16 francs per kilogram, or 5s. 9d. per lb., it would be cheaper than galvanized wire quoted at 0.75 franc per kilogram, or 3½d. per lb., as, weight for weight, it is 24 times a better conductor of electricity.

The Paper contains an elaborate description, with illustrations, of the Cowles electric furnace, and concludes with a comparison as to cost and efficiency, under various conditions, of a cannon in gun-metal and in special aluminium bronze.

Although the nett cost of the aluminium contained in its most valuable compounds, as above stated, does not exceed 4·50 francs per kilogram, or say 1s. 8d. per lb. (and there is no doubt that ere long this will be considerably reduced), it is at present quoted at 20 francs per kilogram, or say 7s. per lb.

W. S. H.

[Some of the above figures appear to need correction; for example, aluminium at 5d. per lb., or 46s. 8d. per cwt., would compare on equal terms with steel at 1½d. per lb., or 16s. 4d. per cwt.; while the present selling price of the chief aluminium compounds appears to be calculated at the rate of from 11s. to 12s. per lb. for the pure aluminium contained. The comparison instituted between gun-metal and aluminium bronze for cannon also appears to need considerable correction.—W. S. H.]

A New Alloy of Aluminium. By H. LECHATLIER.

(Bulletin de la Société d'Encouragement, Paris, 1887, p. 485.)

Mr. Bourbouze has produced a new alloy of aluminium, which possesses very nearly the same qualities of lightness as the pure metal, and, in addition, the great advantage of being readily soldered, which will lead to a considerable extension of the uses of aluminium. Tin, which easily alloys with aluminium, cannot be used directly for soldering. But Mr. Bourbouze remarked, that impure tin, which had already dissolved aluminium, acts with the greatest facility on the pure metal; and that that alloy, after solidification, is equally acted on by pure tin. He was thereby led to rub the heated aluminium with an alloy of this metal, containing 45 per cent. of tin; then to solder the surfaces thus prepared in the usual manner. The alloy of aluminium with 10 per cent. of tin, also possesses the property of soldering with tin, having the useful qualities of the pure metal.

The density of the new alloy, compared with that of pure aluminium, is as follows:—

	Aluminium.	Aluminium +10 per cent. Tin.
Density	2·5	2·8
Melting-point	{ 650° C. 1,202° F.	{ 635° C. 1,173° F.

It is susceptible of taking a fine polish, and does not tarnish when exposed to air. By cold-hammering it acquires a certain degree of elasticity which facilitates its use.

D. K. C.

The probable duration of the Sulphur Mines of Sicily.

(Rivista del Servizio Minerario nel 1885, p. 55.)

For some time past the mining engineers of Sicily have been engaged in the study of the question of the possible quantity of sulphur remaining unwrought in the mines of that country; but it is only since a general geological survey has been established, and the keeping of exact mining plans has been made compulsory by the government, that any estimate based upon other more or less ingenious theoretical speculations has become possible. From the newer data now available a report was prepared in May 1885 by Messrs. Mottura and Conti, which is considered to be a fairly accurate approximation to the solution of the problem. The conclusions, which alone are given in the present report, are as follows.

The sulphur-producing district is mainly confined to the southern and central parts of the island, extending east and west for about 70 miles, and north and south for about 30 miles, the most important centres of production being grouped about Girgenti on the south coast, and Caltanissetta, about 30 miles inland. Within this area there were at work one thousand three hundred and eighty-seven mines, distributed in groups along a series of isolated basins of lacustrine origin, which, since the deposition of the sulphur, have been subjected to considerable disturbance. These basins for the most part follow an alignment parallel to an axis of elevation which passes in an approximately south-westerly direction from Etna by Sciacca on the south coast, to the point where the Island of Ferdinandea (Graham's Island) was formed by the submarine eruption of 1831. The deposits north of this line have generally a northerly dip, while those on the opposite side dip to the south. There are, however, several important groups of mines which appear to be independent of this axis.

The thickness of the sulphur-bearing formation varies considerably, the maximum observed at Lercara, in the north-western corner of the district, being about 240 feet, while the general average may be about 20 feet. The number of workable beds varies from one to six, the maximum number with a total thickness of from 75 feet to 110 feet being observed at Sommatino, 15 miles south of Caltanissetta; but generally speaking, not more than two or three beds each from 7 feet to 10 feet thick are found together in the same mine. The proportion of sulphur to calcareous matter in the sulphur rock as mined, apart from accessory minerals, is tolerably constant at twenty-two to seventy-six, which is also the relation between the molecular weights of sulphur and carbonate of lime—a coincidence which the Authors consider as proving that these substances were not only deposited simultaneously, but were produced by the same chemical action throughout the district. If the accessory substances, such as clay, gypsum and sulphate of strontia are taken into account, the proportion of sulphur in the

rock is reduced to about 22 per cent. The richest portions of the deposits is usually found where the beds are arranged in curves, concave with reference to the overlying strata, which previously represented the deepest portion of the original lacustrine basins. Sudden changes, whether of dip or direction on the outcrop, are found as a rule to be accompanied with impoverishment of the deposits.

The total quantity of sulphur considered by the Authors as likely to be contained in the deposits now known is about 65,000,000 tons, of which 8,353,091 tons have been extracted between 1831–1885, or since the statistics of production have been kept, and probably about 2,000,000 tons more in times preceding the former date. As the loss in the reduction of the ore is about one-third, the above quantity of sulphur sold represents about 15,000,000 tons of material extracted, which leaves as the stock still to be wrought about 35,000,000 tons, or sufficient to maintain the present annual rate of production for about a century.

The exact figures of the statistical returns for the sulphur mines of Sicily in 1885 were as follows. Exclusive of the product of the Solfatara of the Vulcano in Lipari, 377,132 tons of sulphur were extracted from 2,548,840 tons of rock, or an average yield of 14·79 per cent. The number of hands employed was 28,744, corresponding to a production of 88½ tons of ore, and 13·12 tons of sulphur worth £43 10s. for each person engaged in the work.

The cost of production per ton is made up of the following items:—

	s.	d.
Wages	28	11
Other mining and reducing costs	6	10
	35	9
Freight to seaboard, warehouse, and shipping charges	16	0
Cost per ton free on board	51	9
The average selling price was	66	5
Or a profit of	14	8

As compared with 1884, the price has fallen about 5s. per ton, but a saving in wages of about 2s. has been effected, and the yield per hand employed has been increased about 7½ tons.

H. B.

Charneau's Glass-Furnace. By — BIVER.

(Bulletin de la Société d'Encouragement, Paris, 1887, p. 312.)

Mr. Charneau has designed this furnace in a simple and compact form, on the recuperative principle, less costly than the Siemens and like furnaces, suited for the wants of small glass-works. He employs the gas-producer, in which the fuel is reduced to combus-

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tible gases; the regenerator or recuperator, by means of which the air for combustion is warmed by the heat of the departing burnt gases; and the furnace, properly so-called, which receives the materials to be submitted to the action of the fire. It has been found by experience, that the best results are obtained in furnaces of great length, and holding a large quantity of glass. There are furnaces of recent construction, more than 65 feet in length, and 23 in width, capable of holding 250 tons of materials and melted glass.

Mr. Charneau's modifications apply chiefly to the recuperators. The producers are placed close to the furnace, and the recuperators are placed underneath the basins, from which they are separated by canals, in which the cooler air circulates. The recuperator is a rectangular pile of firetiles in stages, one above another, forming horizontal interspaces, in which each layer or stage is propped and supported on the stage below it. The descending-flue from the furnace conducts the burnt gases to the recuperator, through each alternate interspace of which the gases circulate longitudinally, and descend to the bottom, whence they pass by a flue to the chimney. The cold air for combustion, on the contrary, enters the recuperator at the bottom, circulating transversely through the alternate interspaces, to which the heat of the burnt gases is communicated from above and from below, so heating the fresh air for combustion. The air thus heated passes off from the top of the recuperator, by the canal already mentioned, and joins the combustible gases at the entrance into the furnace, where they ignite.

The Charneau furnace promises to be very useful in the manufacture of bottles, where low cost of production can be combined with a very limited production. According to Mr. Charneau, the cost of a furnace on his system, capable of turning out daily about five tons of glass merchandise (say 6,000 bottles), and consuming $4\frac{1}{2}$ tons of coal, would not exceed £600.

D. K. C.

On a Theory of Pyro-Electric Phenomena. By P. DUHEM.

(Journal de Physique, 1887, p. 366.)

The Author commences with a reference to the original discovery of these phenomena in tourmaline, and later on in other crystals, and to the theory of thermo-electric phenomena established by Clausius and Sir William Thomson. The fundamental fact he seeks to explain is the production of an electromotive force between two faces of a piece of tourmaline at a different temperature from that of the surrounding atmosphere. The theory of thermo-electric phenomena shows that an electromotive force is determined by different points of a conductor not being at the same temperature, and its structure not being homogeneous. As regards the latter

point, the Author assumes with Bravais a reticular structure in crystals, and then applies the principles of thermodynamics to this question, as well as to that of piezo-electricity, produced by compression of crystals, which raises their temperature above that of the surrounding atmosphere.

According to the Author's theory, piezo-electric phenomena are the same as pyro-electric, in which heating takes place by compression, and pyro-electric phenomena are simply thermo-electric produced in conductors in which the want of homogeneity is due to reticular structure. If this theory is correct, thermo-electricity, pyro-electricity, and piezo-electricity, are alike, and may be treated rationally by means of thermo-dynamics.

E. F. B.

Utilization of Wind for Producing and Storing Electrical Energy. By L. VIGREUX.

(Le Génie Civil, vol. xi., 1887, p. 390.)

The installation which has recently been put up by the Duke de Feltre, at Cape La Hève, near Havre, with the object of utilizing the varying power of wind for producing and storing electricity by the aid of accumulators, consists of a Halliday windmill, with a possible efficiency of 20 HP.; two dynamos of variable velocity, like the windmill, furnishing with little change of efficiency a current whose difference of potential is constant, but whose intensity varies with the velocity of the machines; and lastly, accumulators charged by the dynamos. Arrangements have been made for rendering the working absolutely automatic; and the Author has ascertained by experiments that the conditions required have been fulfilled. The system is to be applied to the illumination of one of the lighthouses at La Hève; and the Author promises to supply full information of the results attained.

L. V. H.

On the Employment of Dynamos in Telegraphy.

By P. H. LEDEBOER.

(La Lumière Electrique, vol. xxv., 1887, p. 301.)

In the working of telegraph lines either a positive or negative current is used, according to the apparatus to be actuated, and sometimes both currents are required. Mr. Picard, in his system of telegraphing by means of dynamo currents has, therefore, had recourse to two machines, one having its positive pole, and the other its negative pole to "earth." Gramme dynamos of the ordinary workshop type are employed, the electromotive force of

each being 100 to 110 volts. Each machine has one pole joined direct to the earth-plate, the other being connected to one end of a resistance-bar of about 5 ohms. This resistance is divided into equal parts, and has its other end to "earth." Branch wires are led from the various divisions of the bar to suitable terminals, which correspond to a scale of potentials ranging from 100 to 0, a terminal being available for each decrement of 5 volts. From these terminals insulated wires made up into a cable are carried to connection-boxes fitted with concentric rows of binding screws, by means of which these wires are put into communication with others leading to the different telegraph instruments. There are two "potential scales," one for each machine, so that either positive or negative currents can be utilized at will. A box of resistance coils from 40 to 400 ohms can be inserted between the potential scales and the manipulating keys, in order that the maximum current may be limited to $\frac{1}{2}$ ampere, if by accident a short "circuit" should have been established.

When a machine is running empty, about 20 amperes of current are expended; with a difference of potential of 110 volts, this loss of energy is equivalent to three electrical horse-power, or to a consumption of 5 to 10 kilograms of coal per hour. The Author points out that in some previous applications of a dynamo by Mr. Schwendler and others for working telegraph lines, it was sought to utilize the main current either for maintaining an electric lamp or some other purpose, whereas Mr. Picard has sacrificed this supplementary object, and by so doing has attained regularity of transmission, and the choice of a current of any potential between 0 and 110 volts.

The system is in use in the central office in the rue de Grenelle, Paris, and the results obtained are very satisfactory.

J. J. W.

Testing Dynamos. By — HUMMEL.

(Electrotechnische Zeitschrift, 1887, p. 353.)

In certain cases the approximate total efficiency of two dynamos can be readily determined by Cardew's method, which is, however, inapplicable to the testing of a single machine. With the Author's arrangement, the energy absorbed by any given machine is deduced from the electrical measurements of a dynamo, which may be called the standard machine, or D_1 . The output of this standard, with any definite current strength and potential that may be decided upon, and at a certain number of revolutions, is obtained beforehand by means of a brake. The measurements were made in two series. In the first, the current strength was maintained constant, whilst the speed and potential varied within wide limits; in the second, the speed was kept uniform, and the current and potential altered. The load on the brake during each

test was changed according to the output. Curves representing the results obtained were plotted out, so that the amount of mechanical work available at the axle of the standard dynamo is at once known, or can be readily computed by means of a simple interpolation whenever the current strength, potential and number of revolutions of the machine are at hand. This graphical representation of the working conditions of D_1 has also been utilized to determine the energy absorbed by various experimental machines, shafting, gearing, &c., as well as the loss due to currents in different rings for Schuckert's machines, and in the armature disks, &c.

The results obtained by applying the Author's method in order to deduce the efficiency of a new machine, are given in tabular form, and the corresponding curves are shown.

J. J. W.

Direct-working Morse Recorder for Long Cables. By O. STÜRMER.

(Centralblatt für Elektrotechnik, 1887, p. 517.)

The apparatus described by the Author is for working an ordinary Morse receiver on long subterranean cables "direct," that is, without the necessity of dividing the cable into sections, and using translation instruments, as is now done.

The principal feature of the system described by the Author is the attraction of the armature of a sensitive polarized relay to its working stop by means of a short positive or negative current, and the consequent closing of a local battery. The current from the latter then releases one of two separate horizontal levers, the mechanical action of which determines the duration of the local impulse and formation either of a dot or dash on the slip of a Morse receiver in circuit with the local battery.

The spacing between each elementary signal of the Morse code being equal, the upward or non-marking movement of the levers must occupy the same length of time for each, but the downward or marking motion must, as regards its duration, be in the ratio of 1 to 3, as the dash is three times the length of a dot. By means of a simple mechanical contrivance, the lever for dots completes its function in a third of the time required for the recording of a dash during the motion of the other lever.

Let the front plate of an ordinary Morse ink-writer be considered as divided into two equal portions, one to the left and the other to the right of a vertical central line, and the apparatus so arranged that all the supplementary parts required for the signalling of dots lie to the left of this line, and of dashes to the right-hand side. The former accessories are, in the following description, distinguished by capital letters; the latter, which are in reality a duplicate set, by small letters. To the front plate of the Morse receiver are fixed two axes, each carrying a fine-toothed

steel wheel, *Zz*. Under each wheel is an electro-magnet, *Ee*, and armature; the latter carries an axis, on which a brass horizontal lever, *Hh*, can turn. The disk-shaped part of the lever on the axis is toothed on the edge which adjoins the steel wheel, so that the lever is in gear with the latter directly the armature is attracted. The wheel *Z* has a speed of 3, and *z* of 1. Each armature ends in a contact tongue, near which is a stud in permanent connection with "earth." In the normal position of rest, each lever is held against a stop by means of an antagonistic spring, or a counterweight; at the end of the lever, and insulated therefrom, is a steel pin. The downward motion of *Hh* causes this pin to press against a spring, *Ff*, which is thereby put out of contact with a screw *Kk*, fixed to a small brass bar that slides in a grooved frame *Mm*. To this frame is connected one end of the coils of a small electro-magnet *Cc*, the other end being joined to *Kk*. The polarized receiving relays, *Pp*, are very sensitive; *P* responds to a positive, and *p* to a negative current. The working contact of the relay is in connection with one end of the coils of *Ee*, the other end of which is joined to *Mm*. The coils of the Morse instrument, and those of *Ee*, are in circuit with a local battery, which is closed as often as relay *Pp* is actuated by the incoming positive or negative line current. The transmitting-key for sending double currents has two levers, *Tt*, separately mounted. The axis of *T* is connected with the line terminal on the front plate of the Morse ink-writer, and its back-contact with the axis of *t*. The back-contact of *t* is joined to one end of the coils of *P*; the other end of these coils is in connection with one side of the coils *p*, the opposite side of which is to earth.

The course of a negative current sent from the transmitting-station, by depressing momentarily the right-hand lever *t* of key, is as follows: From cable to line terminal (at receiving station), axis and back-contact of *T* to the same parts of *t*, from back-contact of latter through coils *P* (the armature of which is more firmly pressed against the rest-contact) to coils *p* and earth. As the armature of *p* now makes contact with the working stop, the circuit of the local battery is closed, and its current traverses the coils of *e*, as well as those of the Morse receiver. The armature of *e* is attracted, thus bringing *z* into gear with lever *h*, which is consequently moved downwards until the insulated pin causes spring *f* to break contact with *k*, and brings the coils of the small electro-magnet *c* in circuit with the local battery. These coils now act on the armature of relay *p*, and move it against its rest-stop, whereby the local circuit is interrupted, and the various parts of the apparatus resume their normal position. The time occupied by lever *h* in falling from its state of rest till contact is made with *f*, is regulated by the wheel *z*, the speed of which determines the length of the dash. When a positive current is sent, the foregoing operations are performed by the left-hand half of the apparatus, and a dot is recorded on the slip.

J. J. W.

The Efficiency of Small Electro-Motors. By E. H. CLIFFORD.

(Proceedings of the American Academy of Arts and Sciences, vol. xxii., 1887, p. 493.)

The Author gives the results of tests made at the Massachusetts Institute of Technology, by Messrs. F. A. Pickernell, H. G. Pratt, D. P. Bartlett, and himself. The experiments were exclusively devoted to the determination of efficiencies; governing and smoothness of running under different loads being disregarded. The instruments used in the determination of the current and electromotive force were Sir William Thomson's current- and potential-galvanometers. These had previously been carefully calibrated, and found to be correct to within 0.2 per cent., in the positions in which they were used in the tests. In cases where the compensating-magnets had to be used, their intensity was carefully determined on each day of use; as far as possible, however, the use of the magnets was avoided. For measuring the power given out by the smaller motors, a raw-hide belt or a cotton cord was passed completely round a brass pulley on the motor-shaft; the upper end being attached to a spring-balance, and the lower end to a scale-pan. By varying the weight in the scale-pan, the speed of the motor could be changed. A Chatillon balance, weighing to $\frac{1}{2}$ oz., was used. In the tests on the Gramme magneto and the Gramme "small-light," the machines were placed in a cradle dynamometer, a modification of the form devised by Professor Brackett, of Princetown, and a dynamo machine was used as a friction-brake. By closing the circuit of the dynamo through greater or less resistance, the work done, and consequently the power absorbed by the brake, could be varied. For accurately measuring the speed, the speed-indicator from a small siren was used. This was connected to the motor by an endless band, passing from the pulley on the motor-shaft to a pulley of the same diameter as the siren. The power required to run this indicator was excessively small, and, in computing the work done, was not considered. The slip of the belt was negligible, as shown by numerous tests. With the Gramme magneto and the Gramme small-light, a continuously-recording engine-counter was used, connected to the motor by means of a flexible spiral spring.

Thirteen motors were tested, a short description, or reference to a published account, of each of which is given by the Author.

The Author's Table II gives full details of the tests of the model Edison machine. The motors tested were, with one exception—the Gramme small-light machine—intended for very light work, and the efficiencies were therefore not nearly so high as would be shown with larger machines. In a Paper on "Electro-Motors and their Government,"¹ Professors Ayrton and Perry state that motors may be constructed to deliver 1 HP. per 100 lbs.

¹ Journal of the Society of Telegraph Engineers. 1883, p. 301.

of dead-weight. Table III does not support this conclusion; and the Author thinks that, for moderately small motors, 300 lbs. per HP. would be a closer figure, although with larger motors this would be considerably reduced.

TABLE I.

Name of Motor.	C.	E. M. F.	HP.	Maximum Efficiency.	Speed.
	Amperes.	Volts at Motor terminals		Per cent.	Revolutions per Minute.
Griscom	3·94	6·74	0·006	17·0	1,400
Ayrton and Perry	14·40	11·10	0·082	38·4	831
Gramme "Small Light" . .	5·29	157·60	0·945	84·5	2,227
Gramme Magneto	12·60	27·40	0·138	29·8	2,067
Thompson	4·90	8·50	0·012	21·7	2,370
Deprez	4·74	10·40	0·011	16·6	2,140
Monarch	4·85	5·78	0·004	10·1	578
Cleveland	6·78	12·00	0·054	49·8	1,360
Model Edison	0·82	90·50	0·051	51·4	4,065
Diehl 1	7·65	16·50	0·021	12·3	4,180
Diehl 2	6·12	15·10	0·031	24·9	2,480
Hill 1	4·77	10·30	0·010	14·8	2,036
Hill 2	5·04	15·10	0·032	31·6	3,030

TABLE III.

Name of Motor.	Weight in Pounds.	Maximum HP. Delivered.	HP. per Pound Weight.
Griscom	2·80	0·0202	0·0072
Ayrton and Perry	39·00	0·1738	0·0045
Gramme Small Light . . .	172·00	1·3160	0·0077
Gramme Magneto	70·00	0·1512	0·0022
Thompson	6·30	0·0138	0·0022
Deprez	9·60	0·0138	0·0015
Monarch	6·10	0·0041	0·0007
Cleveland	18·50	0·1290	0·0032
Model Edison	15·25	0·0544	0·0036
Diehl 1	9·50	0·0209	0·0022
Diehl 2	20·00	0·0309	0·0015
Hill 1	7·00	0·0120	0·0017
Hill 2	16·00	0·0374	0·0023

F. G. D.

Transmission of Motive-Power by Electricity. By — DEHENNE.

(Mémoires de la Société des Ingénieurs-civils, 1887, p. 295.)

Experiments have been made in the laboratory of the Compagnie Electrique, Paris, on the transmission of motive-power to great distances by means of electricity. These experiments, initiated by Mr. Hippolyte Fontaine, comprised the electrical transport of

an initial power of about 100 HP., against a resistance of 100 ohms, with an efficiency of 52 per cent.

Many applications of electricity for the transmission of power have been made. Transmission is easily effected where the power does not exceed 30 HP., nor the distance 2 kilometres, or $1\frac{1}{4}$ mile. On the contrary, there is considerable difficulty for higher powers or longer distances, especially longer distances; and it is necessary to reduce the intensity of the current, and augment its electromotive force, in order to obviate the loss of the greater part of the disposable energy in the line.

A four-valve steam-engine of Farcot's, nominally of 60 HP., working with steam of 5 atmospheres, develops 95 HP. at the fly-wheel, which is $16\frac{1}{2}$ feet in diameter, and makes 55 turns per minute. By a band from the fly-wheel, an intermediate shaft, making 180 revolutions per minute, is driven, from which four dynamos are worked by means of two $6\frac{1}{2}$ feet pulleys, and four friction-wheels, constructed of compressed paper, $15\frac{1}{2}$ inches in diameter, 10 inches wide, mounted on the Gramme dynamos, and driven by the pulleys by contact. Each machine oscillates on a pivot placed below it, so that the weight of the machine itself determines the pressure of the friction-wheels on the pulleys. By means of a fast-and-loose coupling, the friction-wheels can be promptly placed in or out of contact with the pulleys. The whole system, pulleys comprised, is contained in a space $11\frac{1}{2}$ feet by 12 feet. The intermediate shaft is about 20 feet from the fly-wheel-shaft.

The receiving apparatus is simple. The dynamos are mounted end to end, on a stone foundation, and are connected together with india-rubber couplings. They make 1,200 revolutions per minute. They occupy a space of about 23 feet square, which includes the connections for the brake.

The following are the results of experiments made in July, 1887:—

Mechanical power disposable on the periphery of the fly-wheel of the steam-engine	95 HP
Mechanical power delivered at the brake from the receiving apparatus	50 HP.
Resistance of the intermediate conductors (this resistance is that of a copper-wire 5 millimetres, or about $\frac{1}{4}$ inch in diameter, $77\frac{1}{2}$ miles long)	100 ohms.
Number of volts at the origin of the conducting line	6,700 volts.
Intensity of the current	8 amperes.
Ultimate efficiency	52·52 per cent.

D. K. C.

Menges' Automatic Regulation of Electric-Lighting Circuits.

By A. HILLAIRET.

(La Lumière Electrique, vol. xxv., 1887, p. 219.)

The essential feature of Mr. Menges' arrangement is an electrical contrivance which modifies the regulation effected by the ordinary governor of the engine.

As regards a parallel system of distribution worked with a constant difference of potential, the regulation is attained by means of the variation of the total current; on the other hand, when a constant current is employed, the varying difference of potential at the terminals of the machine is utilized for the purpose. With the first method, the total current passes through the coil of the electric regulator; but with the second, only a derived current traverses it. The regulation is rapid, as the only hindrance is due to the inertia of the various parts of the engine and dynamo, and not to any variations in the magnetizing field.

To the base of a Porter's loaded governor is attached one end of a lever, the other end being movable about an axis held in a fixed upright. This lever carries the iron core of the coil through which the current passes.

Let P be the weight of each ball of the governor.

Q „ „ load (Porter's).

R „ „ iron core.

F = effort to be overcome, in order to move the throttle-valve, which is assumed to act in the direction of the axis of the governor.

l = length of the rods, which are taken as equal.

a = angle of inclination of the rods.

w = angular velocity of the governor.

$f(y)$ = action of the coil on the iron core in the contrary direction to that of the weight R , y representing symbolically the variable factor (current or difference of potential) of the circuit.

When the governor is in action, the condition of equilibrium of the sliding ring is expressed by the equation—

$$\frac{b}{a}[R - f(y)] - \frac{P}{g} w^2 l \cos a + 2P + Q + F = 0,$$

whence—

$$w^2 = \frac{\frac{b}{a}[R - f(y)] + 2P + Q + F}{\frac{P}{g} l \cos a}.$$

If w has to be maintained constant, the numerator and denomin-

ator must vary in the same ratio; if w be made variable, the two terms can be altered unequally.

The variations of the angle a being necessarily very limited, those of $\cos a$ are restricted; consequently it is easy to obtain such alterations of the function $f(y)$ as will suffice for any regulation.

For instance, with a given coil, let the ratio $\frac{b}{a}$ of the arms of the lever be altered. This change alone of $\frac{b}{a}$ will allow—

- 1st. Of increasing velocities.
- 2nd. Of decreasing velocities.
- 3rd. Of a velocity sensibly constant obtained with the same variations of $f(y)$.

J. J. W.

Automatic Electrical Water-Level Meter. By E. DIEUDONNÉ.

(La Lumière Electrique, vol. xxv., 1887, p. 351.)

The system of Mr. Parenthou for registering at a distance the variations of level in a reservoir has been so devised as to require only one line wire for the transmission of telegraphic or telephonic messages as well as the necessary currents for recording the rise or fall of the water. The complete installation comprises: an automatic transmitter at the reservoir, a line wire, and (at the receiving office), an automatic recording apparatus, a call-bell worked by relays, and a telephone or telegraph instrument. The transmitter consists of a drum, on which is wound a chain carrying a float suitably counterpoised. The rise or fall of the float with each change of level turns the drum in one direction or the other, and its motion is, by means of a pinion and an intermediate mechanical contrivance of an ingenious kind, imparted to a rocking switch composed of three metal arms, bent to a right angle at the ends, which are tipped with platinum and dip into mercury contact cups. There are six of these cups, three to the right and three to the left of the axis on which the switch is mounted. The function of this switch is to send into line either a strong positive or negative current from the transmitter battery. The recording instrument is composed of two ordinary electro-magnets in the circuit of a local battery; the armatures act on a ratchet wheel and pointer moving around a dial on which a rise or fall of level of 2, 5, or 10 centimetres is indicated according to the proportion given to the gearing of the transmitter. The axis of the pointer carries an arm which registers the indications as a curve on scale-paper carried on a revolving drum. In order that the line current shall actuate the proper electro-magnet so as to indicate correctly the rise or fall of the float, a compound polarized relay of special construction forms part of the recording apparatus. The core consists of two half cylinders of iron, each suspended by a piece of flat spring. The

lower part of each cylinder carries a tongue, which has two contacts, one on each face. There are four screws, two with insulated points and two with platinum tips, so arranged that the tongues, which are polarized by means of a permanent magnet, rest, one to the right against an insulated stop, and the other to the left against a similar stop. The electro-magnets of the indicator dial are connected respectively with the platinum stops, the other end of the coils being joined to one pole of a local battery, the opposite pole of which is connected to the core of the compound relay. A positive current from the transmitter, passing into the line and through the bobbin of the relay, causes one tongue to make contact with the working stop, the second tongue being at the same time pressed more firmly against the rest stop; the current of the local battery traverses one of the electro-magnets, the armature of which works the ratchet, and the pointer indicates, say, a rise. When a fall takes place the rocking-switch moves in a contrary direction, and a negative current, actuating the other tongue of the relay, brings the local battery into circuit with the electro-magnet which registers a fall of water in the reservoir. The arrangement for exchanging messages is as follows:—Under ordinary conditions, the lever of a hand-switch at the receiving station maintains the line in circuit with a “sensitive relay,” so that the transmitter currents (which are three times as strong as those of the telegraphing battery), after traversing the bobbin of the compound relay as before described, pass through this sensitive relay to earth. A supplementary circuit consisting of a small battery, the coils of a second, or so-called “sluggish relay,” and a contact screw, is included in this arrangement. As soon as the armature of the sensitive relay butts against this screw the circuit is closed. The armature of the sluggish relay carries a small crank which acts on toothed wheels, so as to move a small fan in such wise as to prevent this armature from being attracted quite up to its contact stop, and thereby closing the circuit of a second small local battery and an alarm bell. The transmitter currents are of short duration, and can therefore only close the circuit of the sensitive relay, but as soon as the attendant at the reservoir works a key, and sends longer currents from the telegraph battery, the armature of the alarm relay is pulled against its stop, and the bell rings. The official at the receiving station then puts over the lever of the hand switch to another contact in connection either with a Morse instrument or telephone.

Mr. Parenthou's system is in use between the large reservoir at Montrouge and the offices in the Hôtel de Ville, Paris.

J. J. W.

Heating by means of the Electric Current. By P. H. LEDEBOER.

(La Lumière Electrique, vol. xxv., 1887, p. 415.)

In considering the question of heating railway carriages by means of the electric current, the Author first gives the necessary formulas for calculating the amount of work expended to heat a cubic metre of air from 0° to 15° Centigrade, the air being contained in a cylinder having a base of 1 square metre, and its volume being doubled by raising the piston, which is supposed to stand at a height of 1 metre, to twice that height. In this case the expansion of the air is attended by a loss of temperature of about 68°, provided the sides of the cylinder do not allow any heat to escape. Assuming that the difference of temperature between the outer and inner air is 17° (a sufficient allowance for temperate climates), about seventeen times less heat would be required than for the direct method of warming. The indirect system would, no doubt, be difficult of application to railway carriages, but taking the figures given in some correspondence on this question,¹ and admitting that, for a carriage occupied by twenty-nine travellers, about 8,400 calories would be required to raise the temperature 17°, in supplying for each person 17 cubic metres of fresh air per hour, then, according to the formula in Mr. Lippmann's Paper,² the expenditure of work would be—

$$\frac{8,400 \times 430}{60 \times 60} \times \frac{1}{17} = 59 \text{ kilogrammetres.}$$

For a train of fifteen carriages, $15 \times \frac{4}{3} = 12$ HP. would be needed, or 15 HP. if a loss of 25 per cent. be assumed. This result is very different to that referred to in the above-mentioned correspondence, viz., 300 HP., even when admitting that, in the present calculation, only 17° difference of temperature has been taken into account instead of 30°. There is, in fact, as regards the consumption of energy, no obstacle to the application of the system, but the disposition of the necessary apparatus presents a difficulty.

Take, as an example, the heating of a fixed building in place of a train. According to data in Ferrini's "Technology of Heat," the coefficient of transmission of heat from air to water, through a plate of sheet-iron, is 23 calories; that is, a square metre of surface lets 23 calories per hour pass through it when the difference of temperature is 1°. In the case now under consideration the difference is 17°, hence $23 \times 17 = 390$ calories per square metre of surface per hour, so that for the 8,400 calories about 25 square metres would be necessary. If the reservoir has air around it,

¹ "La Lumière Electrique," vol. xxiv. p. 638.² *Ibid.* vol. xi. p. 42.

instead of water, about three times this surface would be required to obtain the same result, provided the temperature of the surrounding air remains constant.

Some further data on this subject will be given in a continuation of the present Paper.

J. J. W.

On the Theory of the Bunsen Photometer. By LEONHARD WEBER.

(Centralblatt für Electrotechnik, 1887, p. 571.)

The practical manipulation for the comparison of different sources of light under this method may in general be included under the three following heads: (i.) Which is the true Bunsen method, where each light is in turn compared with another or auxiliary light, and the ratio of their intensities determined from the two positions thus found; (ii.) Where the lights are directly compared and the vanishing of the transparent spot in the screen determines the equality of illumination, two positions again being obtained according to whether one or other side of the screen is viewed; and (iii.) Where the two sides of the screen are simultaneously observed and their equality of illumination thus secured, one reading alone being necessary.

From the general principles of the physical quantities in question the Author has evolved the necessary equations, by the solution of which is obtained the following general rule, that if the readings in each of the above methods are taken as directed and repeated with the screen reversed, the inequality in the properties of two sides of the screen will be eliminated, and the true ratio will be given by the geometric mean of the four values in the methods (i.) and (ii.), and of the two values in the remaining one, the values referred to being the squared ratio of the distances of the lights from the screen.

By differentiating these equations it is shown that the limits of error are proportional to the observer's power of discriminating differences in illumination, and also to a certain factor which is wholly a function of the physical qualities of the screen, and the numerical reciprocal of which serves as an indication of the figure of merit of the screen in question. The best screen would consist of an opaque board with a dead white surface, while the spot should be as transparent as possible, and reflect the least light possible in the direction of the observer.

A detailed account is given of experiments made with eight different screens, from which it appears that in the ordinary way of using the instrument, without observations on both sides and reversal of the screen, the error in comparison may be over 200 per cent., whereas by adoption of the precautions here given the greatest error does not exceed 3 per cent. even with the worst screen.

The best screen used in the experiments is one formed of white cardboard, the spot being cruciform and made of thin tracing-paper.

The precaution of reversing the screen is thus shown to be a necessity, and between the physical values of the best screen hitherto in use and of one theoretically possible there is such a large discrepancy that considerable improvement may be expected in this direction.

F. J.

New Formula to represent the Maximum Tension of the Vapour of Water. By J. BERTRAND.

(Comptes rendus de l'Académie des Sciences, vol. cv., 1887, p. 389.)

The Author commences with the usual formula in which the specific heats are represented as functions of the volume and pressure respectively. From these formulas the Author deduces two, one of which is not suitable, the other being $p v = R (T + \mu)$, R and μ being constants, and T the absolute temperature. This formula takes the form—

$$\frac{p v}{R} - T = \mu.$$

The Author sought a verification of this formula for vapour of water; the case of saturated vapour, for which alone the figures are well known, gives a constant value for the ratio $\frac{p v}{T + 127}$, a Table being appended to show its degree of approximation, for various values of T , the mean being 2.476.

If the equation $\frac{p v}{T + 127} = 2.47$ be accepted as a fact, there results a remarkable expression for the tension of the vapour of saturated vapour as a function of the temperature.

This formula is—

$$p = G \frac{T^{79.623}}{(T + 126.37)^{89.576}},$$

$$\log G = 34.21083.$$

The Author compares the figures thus calculated with the pressures obtained by Regnault. He further draws attention to the circumstance of the very large numbers whose ratio gives the pressure, and compares it to a balance in which, in order to measure a tiny weight, weights are placed in the opposite scales heavier than a sphere of platinum, having as radius the distance of the earth from the sun.

E. F. B.

Simple Blue Process. H. BOSSK.

(American Machinist, Jan. 23, 1887.)

The materials are: 1°, thin, white, transparent paper, similar to that known as "unprepared paper."

2°, a thin solution of gum-arabic, coloured with Prussian blue carmine, or Indian ink.

Modus operandi.—Draw or write directly on the paper, or trace the original on it. Now spread the paper face up on a smooth surface (fastening with tacks), and cover well and uniformly with dry, finely-powdered Tuscan red or ivory black, distributing and rubbing it in with the palm of the hand. Avoid getting any colouring matter on the back. Examine the sheet by holding it up to the light, and remove lumps with a soft brush. Now turn the sheet face-downwards and saturate it with poppy- or linseed-oil, using a warm flat-iron. The sheet when well oiled should appear of an even shade and unspotted. The coating being thus fixed, the sheet should be washed under a gentle stream of water, which will cause the lines of the drawing or writing to appear transparent on a red or black ground. Then hang up to dry.

Printing.—Use the ordinary blue process, with a paper of good quality, preferably a heavy one. If the ground of the print should appear cloudy on account of the imperfect coating of the negative, add to the second bath a few drops of a saturated solution of chloride of lime, and watch the bleaching. When the ground is perfectly white and clean, wash again in clean water.

W. P.

Professor Cleaves' Method of making Large Blue Prints.

Prof. R. H. THURSTON.

(American Machinist, June 25, 1887.)

By the common method of making blue prints the glass printing-frame becomes very costly, and the whole process very difficult, when large prints have to be made. Professor Cleaves has adopted a process by which prints of any size can be made without a glass frame, and a print 8 feet long by 3½ feet wide was exhibited to the meeting of the American Society of Mechanical Engineers at Washington by Professor Thurston.

Professor Cleaves' apparatus consists merely of a cylinder of a length exceeding that of the widest drawing to be reproduced, and of a diameter such that the longest tracing to be used can be wrapped around it, with sufficient space to spare to give room for the clamps by which it is held. The cylinder is covered with felt, and the sensitive paper carefully wrapped about it, the tracing to be copied being drawn over the whole, and held smoothly in place by spring clamps. It is found to be easy to lay the tracing

smoothly over the surface, and to draw it into contact so perfectly that the work done is even better than that produced by a glass frame and the air-cushion now so successfully used with it.

The apparatus being ready for use, it is mounted on a cradle, and revolved in the sun by a cord driven by any convenient shafting, or by hand. It requires a little more time, but for exceptionally large prints this does not generally matter.

W. P.

Report on Weights and Measures.

Boston Society of Civil Engineers, U.S.

(Journal of the Association of Engineering Societies, 1887, p. 268.)

The adoption of standard time in America, which took place November 18, 1883, has been followed by the introduction of the twenty-four system of notation on the railways of America.

The Briggs standard sizes for wrought-iron pipes and pipe-threads, have been recommended by a Committee of the American Society of Mechanical Engineers; and adopted by the wrought-iron pipe manufacturers of the United States, as well as by the Manufacturers' Association of Brass and Iron, Steam, Gas and Water-works.¹

With regard to the metric system, public opinion in the West appears to be more strongly in favour of the complete adoption of the system than in the East. A Committee of the Western Association of Architects, reported in November, 1886, that a change to decimal subdivisions was desirable, introducing greater ease of operations in written calculations, greater certainty and rapidity in mental operation with numbers of measure, decreased liability to error in figuring drawings, and a general saving of time and anxiety. Interest in the metric system continues to be shown by Civil Engineers, by placing metric scales on plans—a practice that is extending—by the publication of metric quantities in reports, and by the use of metric measures in computations based upon metric constants. The use of the metre is being extended to vertical measurements in the Coast and Geodetic survey.

To facilitate the conduct of reform in weights and measures, Mr. F. Brooks, in discussion, states that the National House of Representatives established, more than twenty years ago, a standing committee on coinage, weights and measures. This committee made two elaborate reports in 1866 and 1879, both in favour of the ultimate adoption of the metric system. It is through the instrumentality of this committee that reform is to be brought about in weights and measures.

D. K. C.

¹ For an account of the Briggs standard, see Paper by Mr. Robert Briggs on "American Practice in Warming Buildings by Steam," in the Minutes of Proceedings Inst. C.E., vol. lxxi. p. 95.

Mauclerc's Fire-Extinguisher. By Col. SEBERT.

(Bulletin de la Société d'Encouragement, Paris, 1887, p. 486.)

The fire extinguisher of Mr. Mauclerc is an application of the system, now well known, according to which the compression of carbonic acid is utilized for causing the violent projection of a jet of water charged with that gas. Most of the apparatus in use is open to the objection of want of readiness at the moment they are required in action. Special portions are concealed, and difficult of inspection.

Mr. Mauclerc fills a reservoir with water, holding bicarbonate of soda in solution. In a special vase, by which the reservoir is surmounted, open to inspection, a solution of tartaric acid is held in readiness. The vase is closed by a screw-plug, and when the apparatus is to be used the plug is unscrewed, and the vase is inverted and screwed into the top of the reservoir. The acid falls into the solution of bicarbonate of soda, and by reaction carbonic acid is rapidly disengaged, and the water is discharged under a pressure of six atmospheres. The discharge-pipe reaches nearly to the bottom of the reservoir, and the water is discharged through it in the manner of a syphon. The nozzle is connected by means of an india-rubber hose to the discharge-pipe. The apparatus has been well tested, and is employed in many factories and public works.

D. K. C.

Steel Armour-piercing Projectiles of the Perm Factory.

By V. BELOSOROFF, Mining Engineer.

(Gorny Jurnal, January 1887, p. 151.)

On the 15th of January experiments were made at the Perm gun factory, with an 11-inch hardened steel shot. It was fired into a 15½-inch Cammell armour-plate, at an angle of 25° with the perpendicular to the plate, and at a range of 350 feet. The projectile penetrated to a depth of 15¾ inches, and recoiled clear of the plate. On examination it proved to be perfectly cold, and must, therefore, have expended all its energy in piercing the armour; there was no deformation or cracking whatever, and the shot might have been fitted with new rings and fired over again.

Experiments in the manufacture of steel projectiles had been commenced at the Perm factory a year before. In July and August of 1886, some 6-inch shot were fired into a 6-inch Kama and an 8-inch Kolpeno plates. Of eight projectiles, five passed through the plates, and two did so very nearly. About 80 tons of steel, similar to that used in the above experiments, were then prepared, and from it a number of 6-inch projectiles were manu-

factured, of which three were sent to St. Petersburg to be tested at the Ochta experimental ground. They were fired into a 10½-inch Cammell plate under an angle of 25° to the perpendicular, at a range of 350 feet. Two of the projectiles penetrated 6 inches, recoiled clear of the plate, and proved to be perfectly uninjured. The third projectile was fired into a 15½-inch compound plate prepared by the Cammell works; it broke into two pieces, the forward end remaining uninjured. 11-inch Krupp shot fired under similar conditions into the same plate were shivered to pieces; and a like fate attended the projectiles manufactured at St. Chamond. The 11-inch projectile, which has just been tested with such satisfactory results, has been made from the same steel, and there is now no reason why armour-piercing projectiles of unrivalled excellence should not be manufactured in the Russian steel-works.

W. A.

I N D E X

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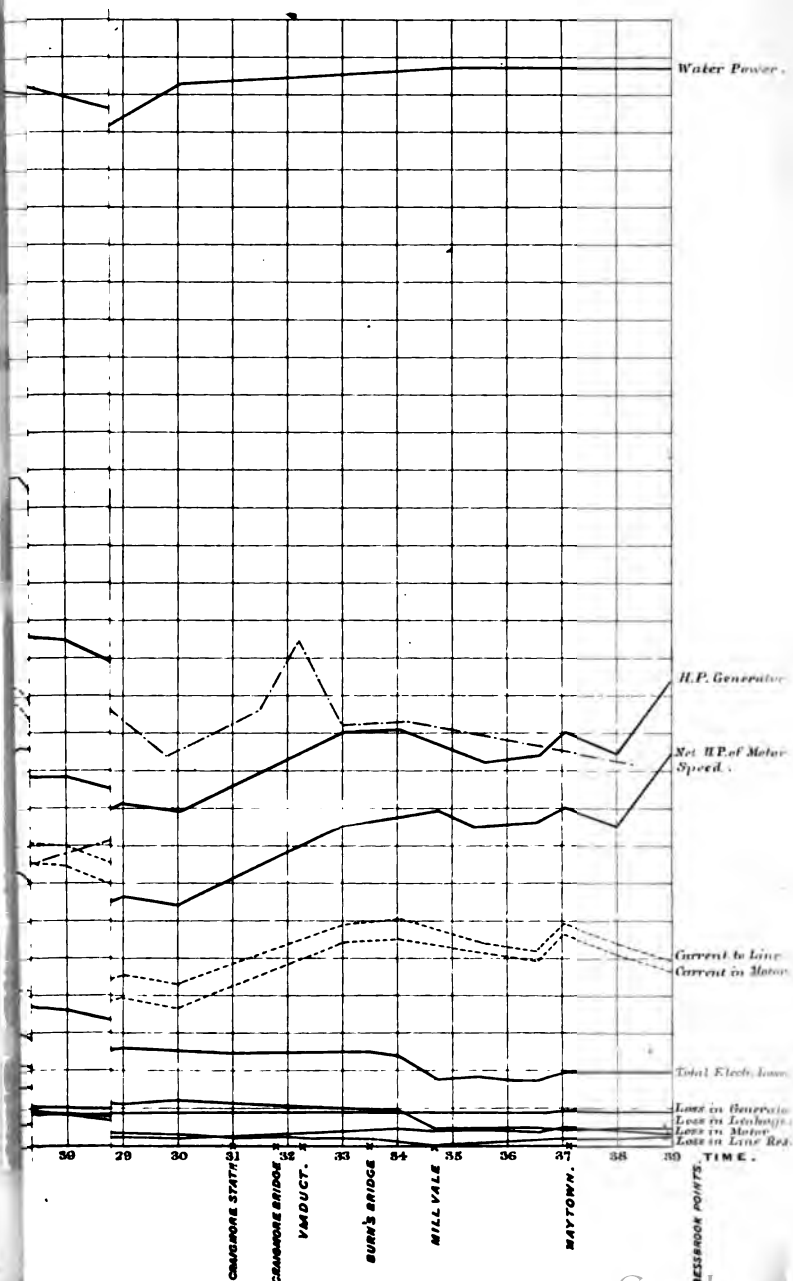
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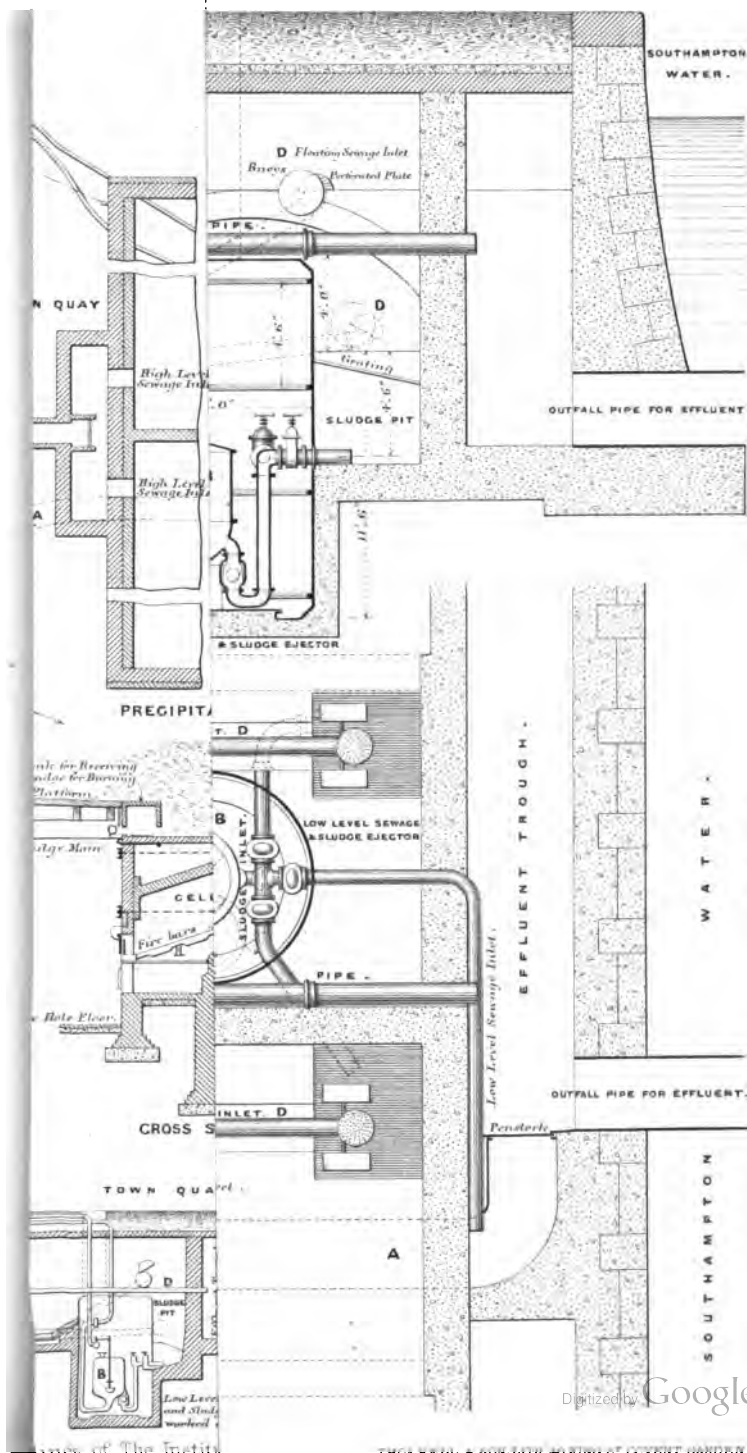
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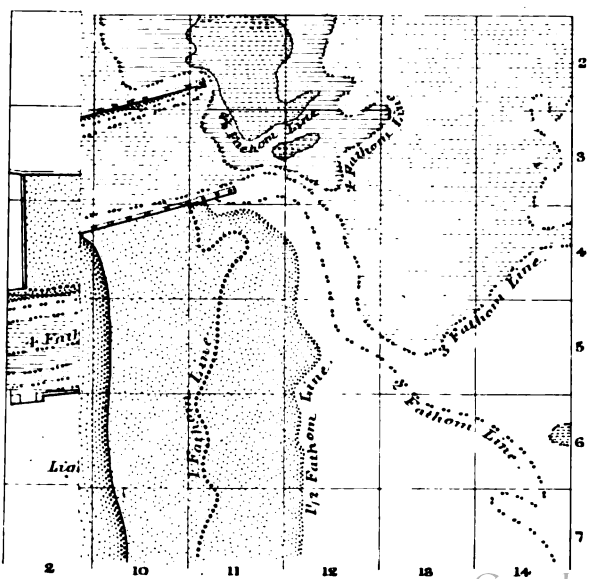
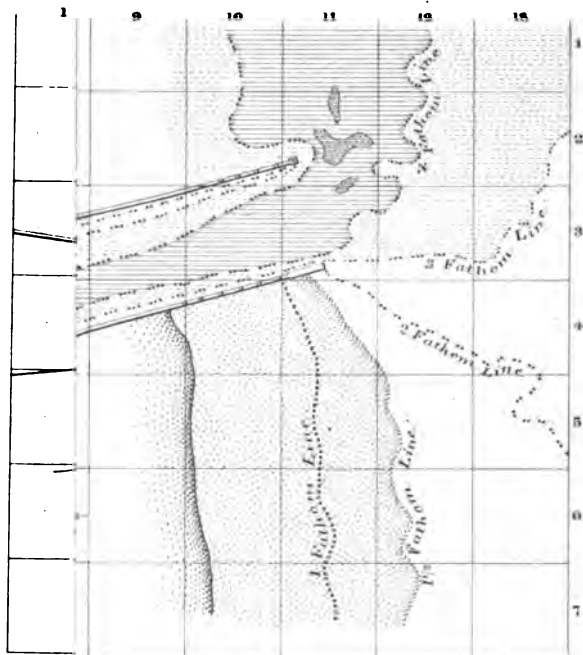
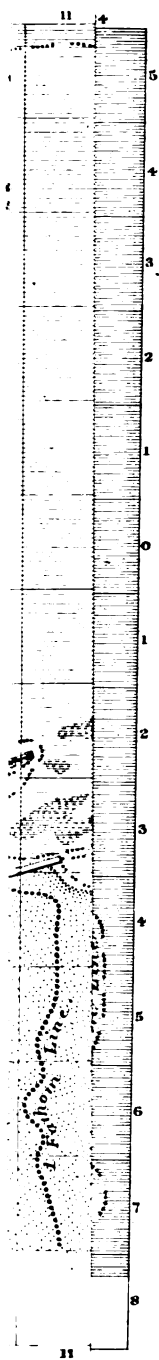
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Fig: 3.



CURVES OF POWER, CURRENT AND SPEED. Digitized by Google

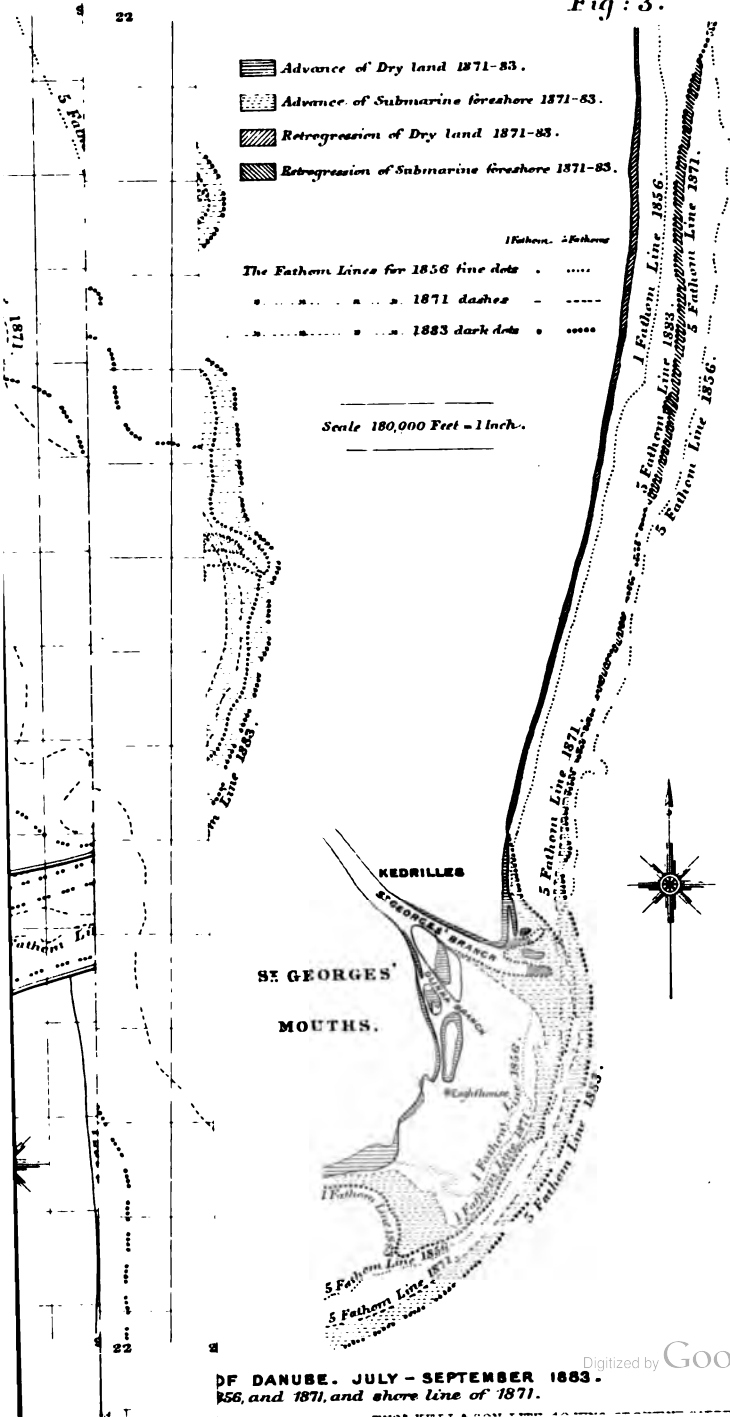




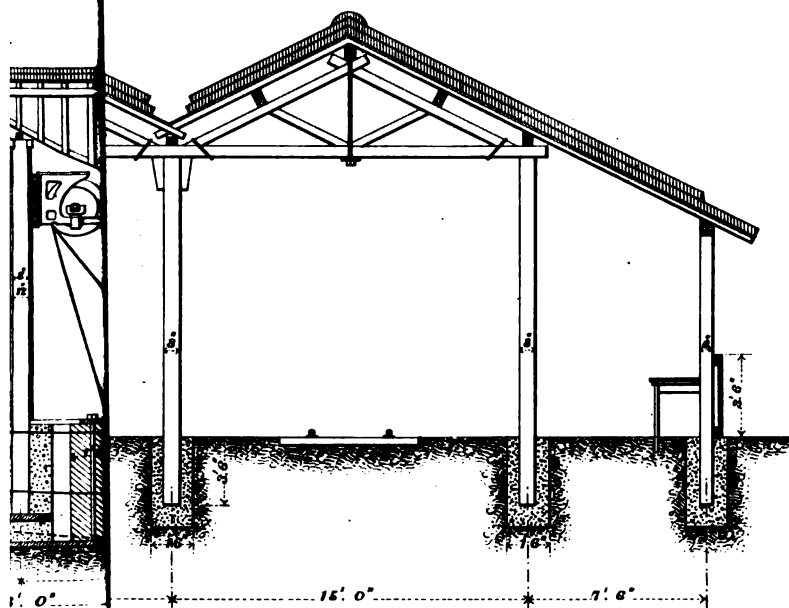
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Fig : 3 .





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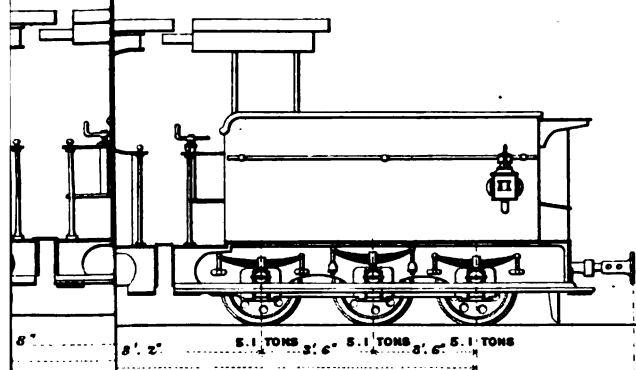
MACHINE

RIAGE SHED

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PLAN.

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FIRE BOX

FIRE BOX, 56 SQ. FT. FIRE GRATE AREA, 10½ SQ. FT.



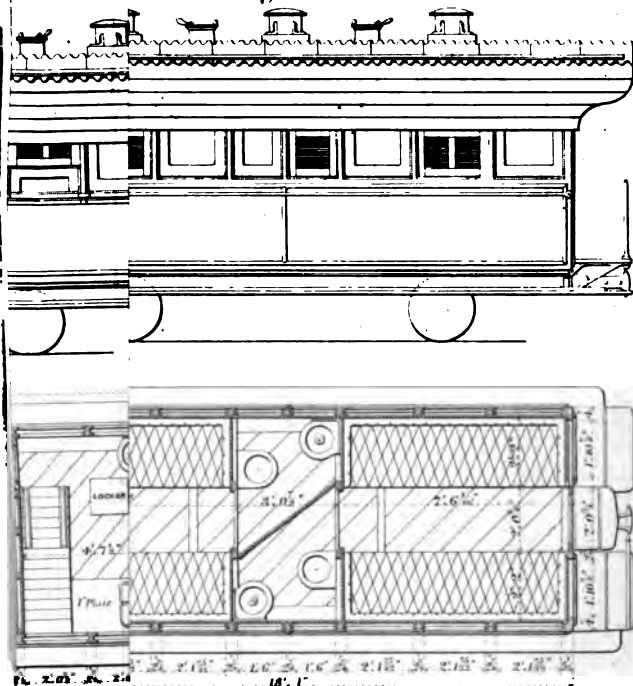
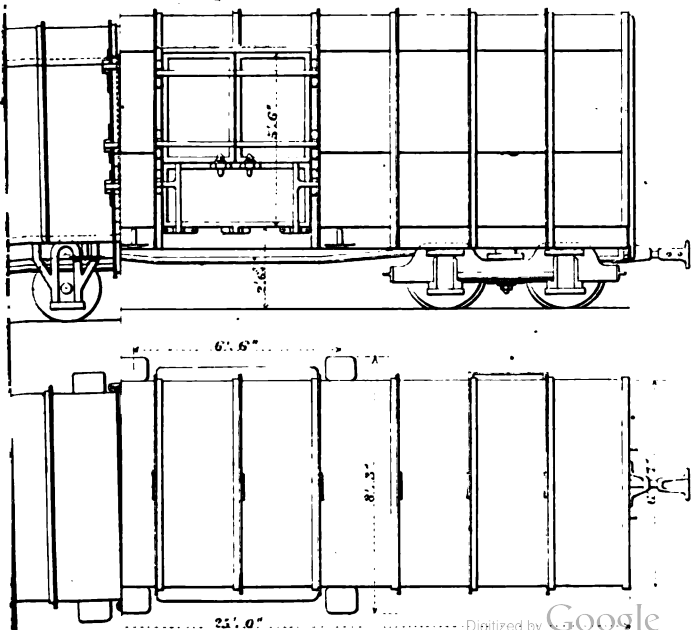


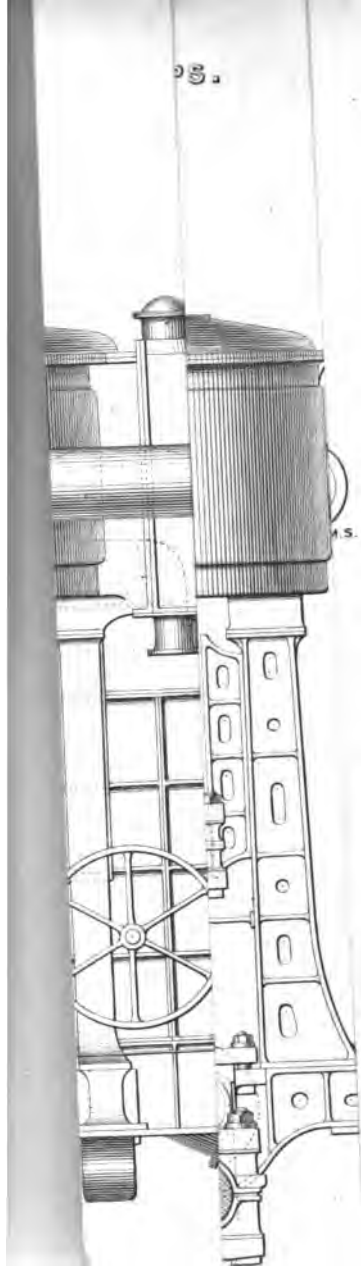
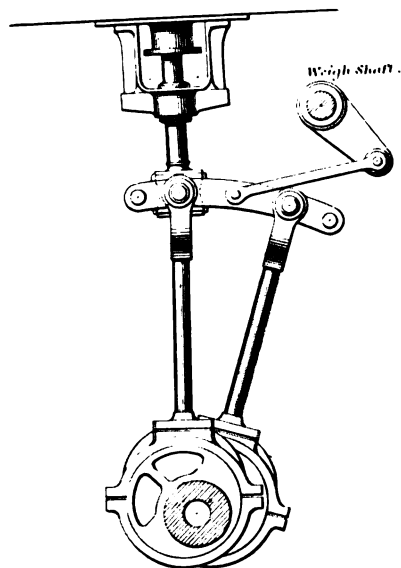
Fig : 11.





REFERENCE :

- M.S.** = Main Steam from Boilers .
M.S.P. = Steam to Mid L.P. Cylinders .
A.S.P. = Steam to Aft L.P. Cylinders .
E. = Exhaust Pipes .
C.W.C. = Condensing water from Centrifugal .
C.W.O. = Condensing water overboard .
A.P.S. = Air Pump suction .
H.W.F. = Hot Well to Feed Tank .
H.W.O. = Hot Well overboard .
S.P. = Starting Platform .





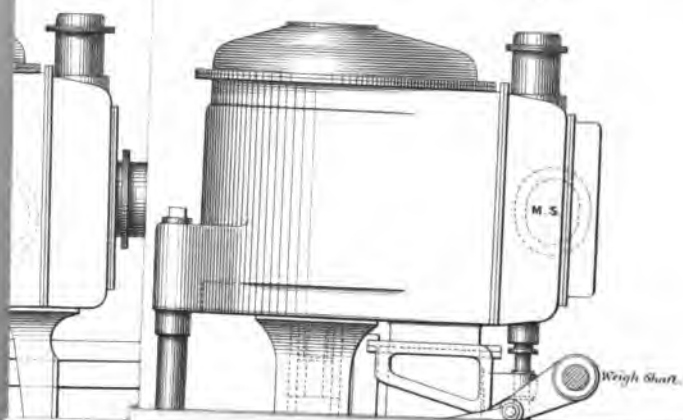
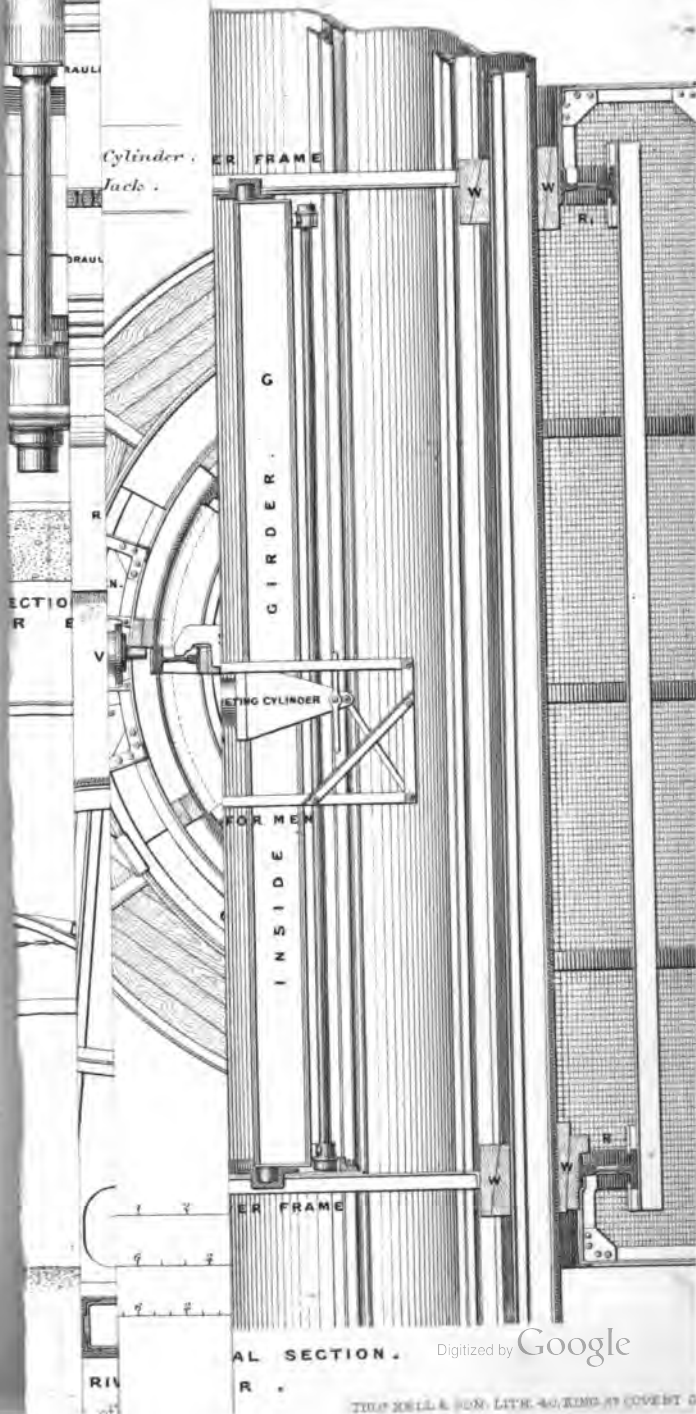


Fig. 10.



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